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The Acquisition Review Quarterly (ARQ) is a Defense Acquisition University (DAU) journal for those who have a responsibility for managing defense systems. The ARQ is designed to serve as a bridge of communication between those who study acquisition management and those who practice it. It will treat specific areas in depth for the serious practioner of defense systems management. Problems encountered, general and unique, and methods of problem solution will be reported. Individual applications of proved problem solutions will be presented for consideration and to provoke more study.

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Whenever masculine nouns or pronouns appear, other than with obvious reference to named male individuals, they have been used for literary purposes and are meant in their generic sense.

Contents

THE ROLE OF DEMONSTRATION APPROACHES IN ACQUISITION REFORM

Larry Lynn

The words "acquisition reform" bring to mind the many efforts instituted by Mrs. Colleen Preston, the Deputy Under Secretary of Defense (Acquisition Reform). In addition, the processes preceding formal acquisition require modification as well, and these must be an integral part of acquisition reform. This article outlines the new Advanced Concept Technology Demonstrations and where they fit in the overall acquisition picture.

Modernization of our forces is essential to assure superior capability across the full range of military operations, with minimum casualties and the flexibility for effectiveness against the wide variety of potential threats. That modernization has at least two essential functions: (1) buying new systems or upgrading old ones, to replace that which wears out or becomes obsolete: and (2) introducing new capabilities via upgrades or new systems. Typically these require a different approach for cost-effective introduction into the forces.

- Conventional acquisition generally applies to the first.
- Demonstration, sometimes followed by acquisition but in many cases as an end in itself, applies to the second.

Mr. Lynn is Deputy Under Secretary of Defense (Advanced Technology).

Acquisition reform, as we intend to implement it, must address both functions with an appropriate mix of both approaches.

The formal acquisition process for major systems, directed by DoD Directive 5000.1 and DoD Instruction 5000.2, is the primary mechanism. Historically, it has been the only path for acquisition of new systems and the introduction of new capabilities via new or upgraded systems. There are many recognized problems with this process, ranging from statutory restrictions to practices and mindsets. Major efforts under the leadership of Mrs. Preston are in process to attack these problems.

We must succeed in substantially improving the increasingly expensive and time consuming acquisition process. With budget constraints and increasing needs resulting from the diversity of threats, we cannot afford the inherent inefficiency that has grown into the process. Therefore, the formal major systems process is needed when: (1) buying large, complex weapon systems such as JSTARS, Tactical Missile Defense systems, and major platforms (e.g., aircraft, ships), and (2) for large quantity procurement of items such as trucks, weapons or munitions.

On the other hand, demonstration approaches represented by the newly introduced Advanced Concept Technology Demonstrations (ACTDs), are important as a cost-saving prerequisite to acquiring new capabilities. These "fieldable prototypes," as recommended by the Defense Science Board, are an important alternative to acquisition in many cases.

New capabilities, as opposed to minor improvements or replacements of existing capabilities, are critical because of the changing situations facing our forces. Additionally, the potential for conflicts to be smaller and highly variable may provide a special incentive for small quantities of unique equipment. For the most part, we will have to thing in terms of specialized units rather than force-wide common equipage.

Demonstrations as a prerequisite to acquisition can provide much better upfront definition and user understanding of new concepts or capabilities. In addition, demonstrations provide a basis for development of modified concepts of operation and tactics to make effective use of the new capabilities. Providing the warfighter with a means to develop concepts of operation which exploit the new capabilities also provides a smoother transition from acquisition to operational utility. The ACTDs executed with militarily significant quantities will prepare the forces for rapid incorporation of the new systems.

Undertaking ACTDs prior to committing to acquisition will provide substantial savings in two ways. First, detailed requirements and functional definitions are established *before* invoking the formal systems acquisition process which makes changes very costly (e.g., formal documentation, detailed "illities," logistics definition). Secondly, the basis is provided for sound judgement in tailoring entry into acquisition. In this latter regard, if the concept, design and maturity are well enough understood, in many cases it will be appropriate to enter

acquisition directly at milestones II or IV (or possibly for very simple equipment involving an existing production base, milestone III). In either case, the demonstration approach leverages the fact that historically, 85-90 percent of the eventual life cycle cost of any system is typically determined by the work done during the first percent of expenditure (i.e., during the definition and early development phases).

Demonstrations in themselves are also an important path for introduction of new capabilities. This is likely to apply in two cases:

- Where quantities of only one or a few are required, such as surveillance systems, upper echelon C3 (command, control and communications), specialized systems, and SOF (special operating forces).

- Where the nature of the capability is such that evolutionary upgrading or deployment is preferred. This includes much of information-related systems which (a) are likely to be the focus of many new capabilities, and (b) can only avoid obsolescence by continual improvements.

For these two cases, demonstrations such as ACTDs are intended to provide a residual capability to the operational forces. It will be much more cost effective to enhance these demonstrations as necessary (e.g., improve sustainability) and to replicate them as required. Appropriate logistics must be included in the considerations.

Much of the publicized work in acquisition reform applies both to formal acquisition and to the ACTD approach. This includes statutory revisions, resolution of data rights issues, and the introduction of streamlined management, inspections, audit and reporting. Obviously, both approaches benefit from increased use of commercial components and practices.

WANTED:
A CONSTITUENCY FOR ACQUISITION REFORM

Dr. Brenda Forman

The subject of "acquisition reform" is a hot political item these days. The Clinton White House is pressing for it. The Defense Department and the Military Services want it. Several legislative initiatives are pending in the Congress to implement it. The burning question is, "will anything really happen this time around?"

"ACQUISITION REFORM" — THERE GOES THAT SONG AGAIN! BUT, WILL ANYBODY SING ALONG?

A degree of weary skepticism may be forgiven, for the subject of "acquisition reform" is a very old song. Indeed, efforts to reform the process by which we design and procure weapon systems date back a good two decades or more — with not a lot to show for it. Over the years, prestigious panels of experts repeatedly have identified essentially the same set of problems: The system costs too much, it takes too long, it discourages innovation by penalizing risk-taking, and when it finally fields a weapon, the technology involved is often already *passé*.

Furthermore, it is hugely expensive. As far back as 1983, the cost of the process was estimated as 20-40 percent of the procurement dollar (Steiner & Montle, 1991). The Office of Technology Assessment (1989) found that the regulatory regime adds anywhere from 10 to 50 percent to the cost of doing business with the U.S. Government.

The Center for Strategic and International Studies (1991) did a case study of an unnamed company doing both military and civilian work. It found that product costs in the military division were higher because their number of

Dr. Forman has spent more than a decade as Director, Marketing Policy, for the Lockheed Corporation. Earlier, she spent 12 years in the federal government, first in the Office of the Secretary of Defense and later in the Commerce Department's International Trade Administration. She developed and teaches a graduate course in the University of Southern California's School of Engineering, entitled "The Political Process in Systems Architecture Design."

administrative personnel was eight times higher per dollar of sales, and twice as high as a percent of total personnel in the commercial division.

The Defense Science Board (DSB) (1993) Task Force on Defense Acquisition Reform found that "unique government procedures" such as "prescribed use of military specification (MILSPEC) parts, special materials handling procedures, quality control and testing mandates, and associated record keeping," could add from 20 to more than 50 percent to the cost of the product compared to best commercial practices. "It is the judgment of the Task Force that tens of billions of dollars per year in efficiencies are achievable."

Reform efforts in the Congress (well-conceived and otherwise) have resulted in an ever-growing mound of legislation. The Acquisition Law Advisory Panel (1993) (the "Section 800 Panel," named after the section in the FY 1991 DOD Authorization Act which mandated it) found that at a conservative estimate, 889 provisions of law had some relationship to acquisition.

And that doesn't count the parade of prestigious panels that have analyzed the system over the years. The 1986 President's Blue Ribbon Commission on Defense Management (Packard Commission) was the sixth major study of defense acquisition done since the Department of Defense (DoD) was established in 1947. The Packard recommendations were widely noted and discussed, but they weren't noticeably implemented. In an effort to do so, Secretary of Defense Dick Cheney launched the Defense Management Review in 1989. It stirred things up through reevaluations and justifications, but really didn't improve matters much either.

Yet, the Packard Commission's recommendations remain essentially as pertinent today as they were eight years ago. Indeed, they are extensively echoed in the most recent (one hardly dares call it the last) analysis of the system's faults, the 1993 report of the DSB on Defense Acquisition Reform. It lists as the "major offending processes in the current system" the following familiar problems:

1. The cost-based contracting system,

2. The systematic application of MILSPECs,

3. The blanket imposition of government-wide and DoD-unique procurement requirements,

4. The unique DoD demand for data rights, and

5. The lack of flexibility in execution of requirements and program definition process with respect to cost, functional capability and specifications.

Déjà vu, anyone?

Thus, both the most prestigious available expertise and the full majesty of the law have repeatedly sought over a period of some 20 years to streamline and rationalize the procurement system, all without perceptible result — except to make the system more burdensome, less efficient and more costly.

The first question is, why? The second question is, can we now at long last succeed? The first question is easier to answer than the second.

IF EVERYONE AGREES THERE'S A PROBLEM, WHY DOESN'T IT GET FIXED?

The rational observer may be forgiven for wondering why 20 years of clear problem identification has yielded no solution. He may mitigate his confusion by bearing in mind the following maxim: *When it doesn't make sense, look for the hidden agenda.* The acquisition system's resistance to change remains puzzling only so long as one assumes that it has only one purpose, i.e., that of designing and procuring weapon systems for the Armed Forces. In reality, the system as it has evolved over the years has an additional multitude of tacit purposes, all of them political in nature and few if any having much to do with the matter of procuring weapon systems.

The problem was excellently illuminated in a seminal study by the Comptroller General of the United States (1992). Essentially, the study says the system is working just fine - because it apparently is producing the results its numerous participants want. "It is the consistency of these outcomes," the study concludes, "and their imperviousness to reforms, contract types, contractors, acquisition strategies, weapon types, critics, military services, administrations, and Congresses — that leads to a conclusion that *the acquisition process may be producing what the participants collectively want or are willing to settle for*"(emphasis added).

The acquisition system, in short, has become the arena in which dozens of participants pursue their individual and institutional agendas. To quote again from the Comptroller General's study, "The key 'problem' with the acquisition process may be that it does such a good job of meeting the diverse needs of its participants."

It is, in fact, intriguing to think of the acquisition process as the quintessential model of the politically successful program. To survive, any program must serve multiple agendas and constituencies, and the acquisition process seems to have perfected the art.

Consider the formidable breadth and diversity of its constituency:

- The Military Services, which enhance their own influence, expand their mission and increase their budgets by initiating and "selling" the programs to Congress.

- The contractors, who have learned how to make money from the system in

face of mounting difficulties imposed by law and regulation. (These may make it difficult to make money on the original contract, but profit may still be made from the inevitable change orders and restructurings resulting from the system's inexorable built-in pressures to over-sell and under-budget the program in order to get it started.)

- Those Members of Congress, who extract contracts and jobs for their districts (whether or not that makes good engineering sense to the program).

- Those Members of Congress who use the resulting political feedback loop to cast themselves as "reformers" and initiate more legislation adding to the plethora of (at times contradictory) existing laws already on the books.

- The media, which gains headlines and Pulitzers for exposing "fraud, waste, and abuse."

- The small businesses, domestic firms, and other groups that benefit from provisions such as Buy America, small business set-asides, and numerous other socio-economic provisions built into the system.

- The multiple auditing and inspection bodies responsible for guarding the taxpayer's interests, who further enhance their mission and reason to exist. (Vice President Al Gore's National Performance Review found that of six million Federal employees, 700,000 are auditors or inspectors general.)

This is a singularly stable political universe, containing an admirably wide range of participants, all of whom get what they want out of it. The only problem is that as budgets shrink in the post-Cold War world, the system is proving decreasingly suited to fulfilling its (ostensible) primary purpose: producing technologically advanced, workable and affordable weapon systems on a timely basis.

WHAT WILL IT TAKE TO FIX IT?

In a 1993 interview, retired Air Force General Don Kutyna declared, "I've been in the acquisition business since 1965. I guess I've seen acquisition reform take place about every 1-2 years since then. Unless they fix the political side, very little will ever change." Air Force Lieutenant General Tom Moorman, Vice Commander of the Air Force Space Command, notes (1993) that, "The real dilemma is the tremendous number of people with a huge interest in the UNreformed acquisition cycle."

This is, essentially, a political problem — and as a colleague succinctly puts it: "Logic has no place in politics; everything else makes sense." Twenty years of Blue Ribbon panels have applied logic to this problem with no perceptible

success. Fixing it will require instead those age-old political skills: building a constituency for reform by identifying and serving multiple institutional and individual agendas without sacrificing the core goal — and above all, sustained, high-level leadership.

In every way, it is a daunting task. Even with the best will in the world, it truly won't get fixed in a hurry. The 1993 DSB report estimates that it will take at least four or five years of sustained political effort to effect any lasting systemic change.

Consider the status quo's constituency, briefly outlined above. That is a formidable political force. Each of its components, moreover, commands its own political resources. Each, therefore, represents a different political problem.

The difficulties any serious reform effort faces are neatly illustrated by the problems encountered by the DoD's "pilot program" proposal in the fall of 1993. The DoD had identified seven pilot programs that were to be exempted from veterans' preference, various labor acts and the numerous socioeconomic provisions currently mandated. Because these aspects of the proposal affected the interests of other Executive Branch departments such as the Labor Department, Veterans Affairs, National Aeronautics and Space Administration (NASA), the Small Business Administration, etc., the DoD proposal had to be coordinated with these organizations before it was submitted to Congress. In the course of that interagency review, every agency except NASA non-concurred in the areas in which it had jurisdiction and where it considered its interests to be threatened.

Every major improvement therefore will be a separate exercise in coalition-building in which the central challenge will be to muster a constituency strong enough to outweigh the one already in place. An absolute prerequisite will be intense, sustained political leadership from the top of government, to include the White House, DoD, and congressional leaders. A knowledgeable House staffer states that, "The Administration needs to create a sense of urgency about this and its importance to them." The question is, will that effort be forthcoming?

WHAT'S HAPPENING NOW?

As of this writing, the political lineup in favor of genuine reform looks cautiously promising. The White House has expressed strong support, and the National Performance Review included procurement reform as a way of streamlining government. Secretary of Defense William J. Perry and Deputy Secretary John M. Deutch are both strong advocates of reform. (Perry is reported to have said he had participated in so many Blue Ribbon Panels on reform over the years that he hoped he could finally make something happen this time.)

Strong supporters also exist in Congress. Currently, the centers of activity are the House and Senate Armed Services Committees (HASC & SASC) (which have jurisdiction over defense acquisition), the House Government Operations Committee and Senate Government Affairs Committee (which deal with gov-

ernment-wide acquisition). This joint effort is essential because the latter two committees have jurisdiction over two of the reform recommendations: greater use of commercial products, and raising the "small purchase threshold" from the current level of $25,000 to $100,000.

But the breadth of the existing system's constituency means that a broad range of other congressional committees also could be involved, depending on how broadly encompassing the proposed legislation turns out to be. (In 1992, for example, the Business Executives for National Security found that 107 congressional committees and subcommittees exercise some degree of Pentagon oversight.) This can vastly complicate the challenge of producing truly meaningful reform legislation because the greater the number of committees involved, the greater the difficulty of reaching any meaningful consensus.

In addition to the committees mentioned earlier, committees which potentially could get involved in this process include:

- House and Senate Small Business Committees, because of the proposal to amend the Small Business Act to raise the small purchase threshold,

- House and Senate Judiciary Committees, because of the criminal implications of "whistle-blowing" legislation, questions of jurisdiction over Federal courts in protests, patent rights, and some of the procurement integrity statutes,

- House Science, Space and Technology Committee, in connection with any proposed changes to the technology transfer provisions of the Stevenson-Wydler Act,

- House Education & Labor Committee, if any revision is included to amend the Davis-Bacon Act, which requires paying workers the prevailing wage on any Federal contract over $2,000, a threshold set in the 1930s [at this writing, the Administration has agreed to put this into a different bill], and

- Different Buy America and socioeconomic provisions could involve other committees (e.g., cargo preference would be U.S. merchant marine, etc.). It will be hard to undo these provisions since many of the originators are still in the Congress.

Thus, reform advocates are confronted with a delicate political balancing act: If they try to limit the committees of jurisdiction involved, they could end up confining the effort so tightly that any improvements would be only at the margin. If instead they try to make comprehensive changes, that could involve so many committees of jurisdiction that the result could be either deadlock or something watered down beyond recognition.

Worse yet, such a diluted outcome could allow Congress to declare victory and do nothing further. This was apparently the defense industry's fear in connection with a bill sponsored by Senator John Glenn in the fall of 1993. But one reason the Glenn bill was framed in such limited terms seems to have been that certain key committees and key members were expected to resist any more significant measures. Meanwhile, the White House was pushing for early passage. So the bill was weakened to get it through the congressional thickets more rapidly.

On the House side, HASC Chairman Ron Dellums and Government Operations Chairman John Conyers, Jr., introduced a small "first-step" bill in 1993, but it made little progress. They have continued to pursue it in 1994.

One new, possibly encouraging feature on the scene is the "Section 800 Panel Report." A high industry official says it is the basis for successful acquisition reform and notes, "If all that could be implemented, we'd be pretty well satisfied."

The report analyzed more than 600 defense-related procurement laws, examined why each was passed, its legislative history and how it was working now. Then it recommended that almost 300 be either repealed, deleted or amended. A knowledgeable House staffer notes this was the first time a review panel had produced a practical guide for dealing with the reform issue. "It's much easier to deal with the laws if you know WHY something was passed. A lot of the Blue Ribbon panel reports just said let's do away with everything and start over. That won't go anywhere. The politics just aren't there!"

WHAT'S THE PROGNOSIS?

There are the usual storm signals. It has become almost politically correct to support "procurement reform" — but that may last only so long as the precise definition of "reform" remains unclear. One committee staffer says, "I can't think of anyone who would say, 'I oppose acquisition reform,' or 'I oppose overhauling the system.' That said, there are a lot of arguments for people to hang their hats on that would probably bog things down."

Another major peril lies in Washington's chronically short time horizon. The American political system is wretchedly poor at dealing with anything long term — and "long term" in Washington terms means anything over two years, the term in office of a Member of the House, at the end of which (or more accurately, about the mid-point of which) the Member begins running for reelection. Yet meaningful reform is going to take several years of sustained political effort. A single administration will be lucky just to get the ball rolling, and that only if it keeps steadily applying the political pressure.

Will the Clinton Administration choose to expend so much political capital over so long a time on such a knotty issue? It's almost unfair to expect it. The subject is arcane and insanely complex. Accurate explanations bore the media and confuse the public, while quick-fix remedies that may actually exacerbate

the problem make the headlines and the sound bites.

Furthermore, the Administration has other major priorities that will take huge amounts of political attention and energy. As we have emphasized here, active White House backing is essential if any progress is going to be made on this issue on Capitol Hill. With that in mind, congressional supporters had aimed to pass legislation before April 1994. To pass important legislation in so short a time is challenge enough; to ensure that the legislation passed is meaningful and truly addresses the problem is doubly challenging.

Meanwhile, industry has its own problems defining what a revised system should look like, which is hardly surprising. For all its frustrations, distortions and illogic, the current one is the only system the industry has ever known. By necessity industry has learned to live with it by adapting to its often contorted demands. A degree of confusion in defining a desirable alternative is therefore understandable. However, to the extent that it causes the industry to sound disunited or undecided, it weakens its effectiveness as an advocate for reform.

When asked to describe the congressional lineup on procurement reform, another House staffer says, "They may not yet have chosen sides. It's before the Archduke Ferdinand has been assassinated." Then he makes an important point. "Procurement reform isn't an end in itself. It becomes a means to another end." For example, he continues, if one of the Services feels that DoD had cut its budget to the point where it cannot fulfill its mission requirements, it might decide that reform was a way to get more bang out of its bucks. But another Service getting what it wanted might decide to stand pat. "Procurement reform," he notes somewhat sardonically, "starts when someone kills a program."

If reform is to succeed, it must be perceived as serving multiple agendas as effectively as does the status quo it seeks to supplant. *Briefly put, reform must have a constituency.* As yet, the size and shape of that constituency are both unclear.

What arguments might help build it? Possibly the most powerful one is affordability. Simply put, we can't afford the current system any more. On several occasions, Secretary Perry has expressed his intention of keeping research and development funding level in real terms, reducing personnel and operations and maintenance funding somewhat — and cutting procurement by 30 percent. If the Armed Forces are to be equipped with the weapon systems they need then their costs must come down. Reforming a system that consumes 20-50 percent of each dollar in overhead would seem to be a sensible way to help achieve that goal.

Another argument arises from a disturbing trend seen in several studies, the most recent one being the 1993 DSB Report: The defense and commercial industrial bases are diverging more widely, and because of the slowness and rigidity of the procurement system, the defense industrial base is lagging technologically behind the commercial one at an accelerating rate. Technological superiority in our weapon systems has traditionally been crucial to our

national security. If that is to continue, then the acquisition system that is undermining it must be reformed.

A third argument arises from industry's plight. Briefly put, the defense industry is in trouble. Senior defense officials are worried. Secretary of Defense Perry and former Secretary Les Aspin have repeatedly come out strongly in favor of reform in order to preserve the defense industrial base, which in turn relates to the confused issue of defense conversion. Whether and to what extent traditional defense firms will be able to adapt to and compete in the post-Cold War marketplace is unclear. If they are to stand any chance at all, the system must be rationalized to eliminate the burden of separate accounting procedures, special certification and record-keeping requirements, blanket application of MILSPECs, socioeconomic laws,trade restrictions, etc., that impede or even preclude any firm from competing in a commercial marketplace.

Will these and other arguments carry the day? Short answer: We don't know yet, because the balance of forces is still unclear. Bear in mind the current system is the result of a long accumulation of political weight on the side of complexity, redundancy and oversight layers. It has become the vehicle for pursuing multiple political goals often unrelated to those of procuring a weapon system, and these goals enjoy powerful constituencies. To rectify that balance will require the mobilization of an equal or greater weight on the side of change and reform.

Will that happen? Once again, the Comptroller General report cited earlier sums it up excellently:

> ". . . better outcomes will require participants to give up something — to ask the acquisition process to satisfy fewer needs . . . The question is whether participants are willing to make the sacrifices needed to achieve these outcomes."

In short, stay tuned.

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CONVERTING THE MILITARY-INDUSTRIAL COMPLEX:

Why It's Difficult

Peter Horton

An examination of the unique characteristics of the management structure and modus operandi of the defense industry shows that these characteristics complicate the industry's conversion to commercial markets. This article argues that the present government initiatives to facilitate conversion through federally funded and managed technology development projects are less likely to succeed than would the infusion of venture capital for entrepreneurial investment in potential commercial projects.

INTRODUCTION

The term "military-industrial complex" was first used by President Eisenhower in his farewell radio and television address to the American people on January 17, 1961. Eisenhower acknowledged that until World War II (WWII) "the United States had no armaments industry. American makers of plowshares could, with time and as required, make swords as well. But now we can no longer

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trust emergency improvisation of national defense; we have been compelled to create a permanent armaments industry of vast proportions...."

However, the most often quoted excerpt is one expressing his concern regarding the "military-industrial complex" and the possibility of "misplaced power." The President's words bear repeating today:

> In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist.

Eisenhower recognized the importance of a strong military establishment, but he also realized a major transition had been made during the mid-1950s from a policy of mobilization, to one of forces-in-being. The new policy called for a large standing military establishment supported by a new industrial entity — the defense industry. The Cold War impact on the defense budget was profound (Figure 1). Now there are about 5 million men and women in the military-industrial complex (down from 6.7 million in 1987), essentially equally divided between the military forces (uniformed and civilian) and the defense industry.

Since the peak spending for weapons in 1986, our military-industrial complex has been undergoing a major transition in response to markedly new world conditions. Industry was asked to beat swords back into plowshares: the buzzword now is "conversion." Severe domestic economic pressures complicated the issue. Concern for the health of the economy and unemployment in particular has brought considerable political attention to the conversion of the human skills and physical resources of the defense industry to commercial markets.

However, it is clear from recent events here and abroad that there remains a critically important role for our armed forces and the industry that supports them. This transition must be managed so as to protect the required industrial base. Additionally, the performance of the military-industrial complex in terms of missed cost, schedule, and technical goals has been unsatisfactory, requiring continued attention. Nonetheless, conversion is now a top priority issue, and we must come to grips with it.

Conversion to non-defense markets was shown to be inherently very difficult during the cutbacks of the early 1970s. Note, on Figure 2, that the 1970s cutback was, in real terms, more severe, 44 percent reduction from 1968 to 1974, than the present one, 17 percent from 1986 to 1992. However, the defense buildup of the 1980s cut short that conversion experiment. Now, while the long term outlook is typically uncertain, signs point to a substantial and more permanent downsizing.

The difficulties with conversion are inherent in the nature of the government-industry relationship. Government manages the defense industry so as to render

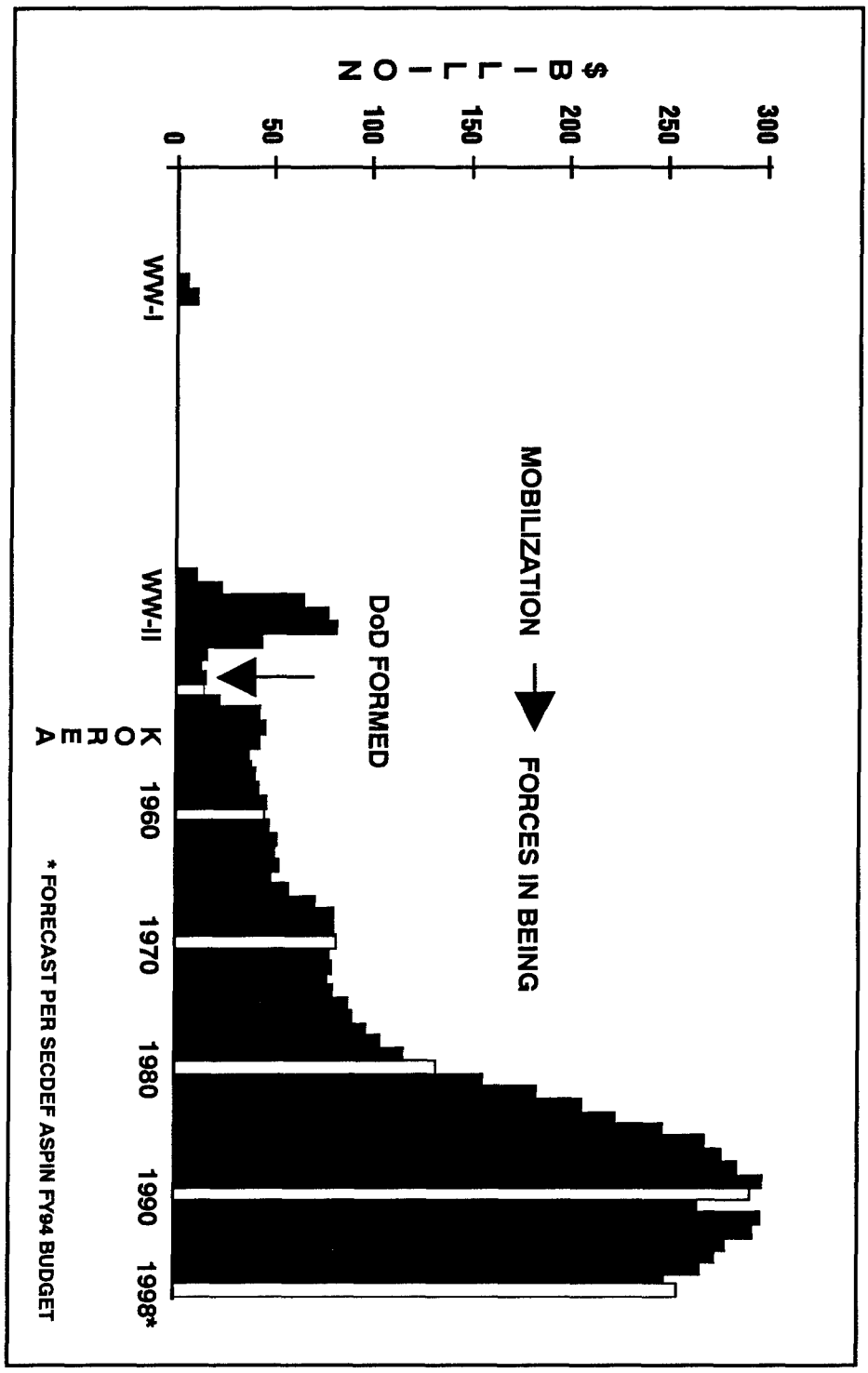

Figure 1. **Defense Outlays**

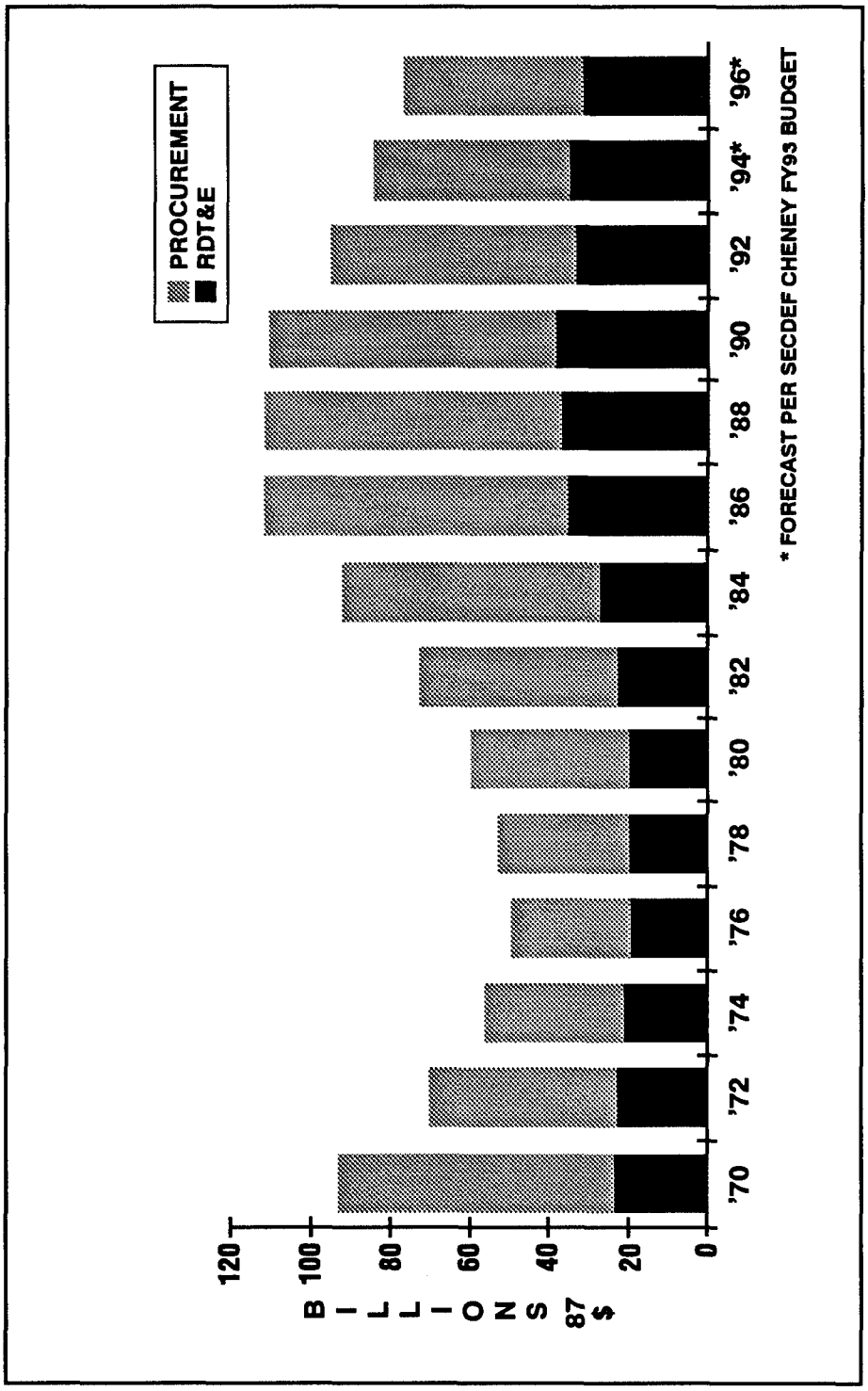

Figure 2. **DoD Weapons Outlays**

it unsuited to compete in nondefense markets without major restructuring. Effective conversion requires more than a stable of advanced technologies supported by sound design and production capabilities.

The genesis of the defense business has, as one would expect, an important bearing on its present management structure and *modus operandi.* During the mobilization buildups for WWII and the Korean War, as Eisenhower noted, the government turned to existing industrial management organizations for war production. In many cases the government provided production facilities. In some cases the government directed noncompetitive contracts to produce existing weapon designs, especially for second sources, which were typically cost-plus-a-management-fee. Generous progress payments eliminated cash flow concerns. Clearly the defense industry was not formed in the entrepreneurial style; it was formed by the government as a national security necessity. The choice of this quasi-free enterprise form instead of a nationalized arsenal system was apparently a deliberate decision, but the long term implications of the choice were not fully thought through.

During the years of the forces-in-being policy the government increasingly treated the defense industry as though it were truly investor-owned free enterprise operating in a market economy. (See Figure 3.) This misperception has contributed to many of the difficulties in the defense acquisition process, and is particularly relevant to the conversion issue.

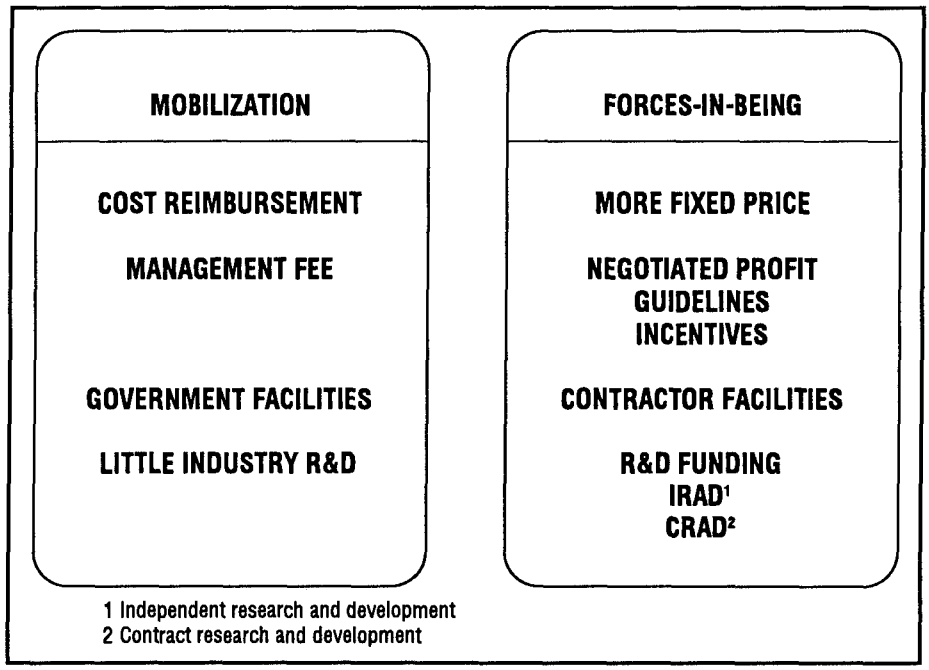

Figure 3. **Changes in Contracting and Funding Methods**

The specialized characteristics of the defense business have been pointed out by several observers over the past thirty years or so. The most significant of these characteristics are:

- One buyer, the government, rather than many;
- Few suppliers for a given system rather than many;
- Market entry difficult;
- Market exit difficult (the government is directed by law, 10 U.S.C. 148) to protect the defense industrial base;
- Prices set primarily by cost rather than by supply and demand — a holdover from the cost reimbursement policy;
- Profits controlled by the customer — a holdover from the management fee policy;
- Competition, particularly at the system level, on an "all or nothing" basis rather than market share; and, of increasing significance,
- The customer is the specifier, banker, judge of claims, and manager of all programs in all respects from start to finish.

In this atypical business, customer (government) involvement directly impacts the three major aspects of industrial activity:

- Business development
- Operational management
- Financial management

BUSINESS DEVELOPMENT

In reality, for the "big ticket" systems that have caused the most concern, the defense industry does not sell products. It contracts to provide a management service — the management of the human and physical resources required to design, develop, and produce defense systems to meet government performance specifications and in accordance with government program budgets, schedules, and management systems. The contract is a promise to deliver. The business development process is successful when a contract is awarded.

The major system contractors are continuously involved in preparing for the

next competition. This business development process requires identifying potential new program starts, and developing and demonstrating the needed technologies and other required resources and capabilities. The elapsed time from official recognition of a new military requirement to award of the first phase of a major new system start can be five years or much longer. During this time industry must perform appropriate preliminary system studies, develop the new technologies required, ensure the availability of the needed plant and equipment, and organize industry teams.

Contractors are selected competitively using a formal source selection procedure based on evaluation of detailed and voluminous written proposals. The competing contractors are primarily concerned with convincing the evaluators that they understand what the government wants done and that they have the capabilities and resources to do it — and do it the way the government wants it done.

An important ingredient in developing a strong, responsive competitive position is market intelligence. This requires knowing and understanding the customer. For the defense contractor, the customer is very complex. Industry cannot develop the required market intelligence effectively through direct contact only with the Military Service buying commands: the proximate customer. Industry also must maintain meaningful two-way communication with all elements of the Services (the using commands, the acquisition agencies, and the planners and programmers), the Office of the President, and Congress. In this context the role of Congress is critically important. Through its control of funding, Congress has direct control of the acquisition process. In the final analysis, Congress determines which programs are started or stopped, where they will be carried out, and at what pace they will proceed.

Industry has an important role in the acquisition planning process. It has a major responsibility for the estimates of technical feasibility, cost, and schedule for new programs, and has the ultimate responsibility to carry out the selected programs. Industry by necessity is a long term partner with government.

Unfortunately, the partnership is stressed because the business relationship between government and industry is adversarial. Industry must compete for new business, not only with other members of industry, but with conflicting priorities and values among the various factions within the government, the customer.

An adversarial relationship between buyer and seller is not at all unusual. Buyers in a free market are always trying to get the maximum possible for the lowest possible price. However, the commercial customer is (usually) buying an off-the-shelf product that can be seen and tested before agreeing to a price. In the case of the defense acquisition process, however, the government is (usually) buying a promise to deliver something that has not been built before. This is especially the case with new, big ticket weapon system development programs.

In short, the defense industry has designed its new business development management system to meet the very unusual demands of defense business. Such a system is not at all suited to non-defense business.

OPERATIONAL MANAGEMENT

Operational management refers to the basic industrial functions of engineering, production, accounting, and personnel. The major departures from commercial practices involve the layering on by the government of many specialized administrative and procedural controls. These are designed to ensure proper program planning and control, and ensure satisfaction of stated requirements and product quality. There are, additionally, special administrative requirements associated with security. All of these special requirements are imposed on top of all the other governmental requirements imposed by, for example, the Internal Revenue Service, the Securities and Exchange Commission, etc. They require the maintenance of many specialized management systems and procedures not required in commercial work.

Much of the "excess" cost of defense industry products has been attributed to these special requirements. Although it can certainly be argued that they are justifiable in the interest of protecting the expenditure of public funds and ensuring the availability of fully effective and reliable defense systems, they do not mix well with commercial business. Most defense contractors segregate their defense from their commercial business, either totally or in part.

A recent Center for Strategic and International Studies report found that most companies that operate in both the commercial and federal markets alter their business procedures in order to sell to the Federal Government and that the cost premium to the government can be substantial; they either physically separate some portion of their operations, or set up a separate data management system to do business with the government. Conceivably, converting defense industrial units to commercial business would require significant realignment and cultural changes.

FINANCIAL MANAGEMENT

Defense industry financial management differs in several major respects from conventional commercial practices. Three of the most significant departures from normal commercial practice are business development, profit and cash flow.

Business Development Costs

A large portion of business development costs is covered by the government in the current period. These costs are covered in two ways:

- Certain costs are allowable as items of indirect expense on current defense contracts. Included are:

— Economic Planning: This includes the costs of generalized long-range management planning concerned with the overall development of the business.

— Independent Research and Development (IRAD): This covers the costs of the contractor's R&D efforts that are not required in support of a contractually covered program.

— Bid and Proposal (B&P): This covers the costs incurred in preparing and submitting bids and proposals, whether solicited or not, on potential Government or non-Government work.

- The research, development, and test and evaluation (RDT&E) portion of the defense budget, currently at a level of about $38 Billion per year, makes Contract Research and Development (CRAD) available on a competitive basis. The CRAD contracts are available in all relevant technical disciplines and range from basic research to advanced system development.

Profit

When price negotiations are based on cost analysis, profit rates are established as part of each contract negotiation in accordance with a structured analysis.

Cash Flow

Positive cash flow is aided by certain special financing provisions:

- Progress Payments amounting to 80 percent (85 percent for small business) of the costs incurred during the period can be paid if requested.

- The Facilities Capital Cost Of Money provision establishes criteria for measuring and allocating, as an element of contract cost, the cost of capital committed to facilities assigned to the contract. (Interest payments are not allowable as contract charges.)

In summary, all of these special characteristics of defense industry structure and *modus operandi* have their origins in the policies applied during the WWII and Korean War mobilizations when it was assumed the undertaking would be relatively short-lived and no thought was given to long-term implications. The realities of the defense industry are still not well understood as evidenced by the major government initiatives to facilitate conversion.

The FY-1993 Conference Report on Defense Appropriations identifies $1,767.01 million in Title VIII — Defense Reinvestment for Economic Growth.

The Conference Report breaks this down to explain where it is contained in the Appropriations Act (PL 102-396 — October 6, 1992) as follows:

Title I -	Military Personnel	$ 294.21 million
Title II-	Operation and Maintenance.	120.00
Title IV-	RDT&E	880.80
TitleVIII-	Reinvestment For Economic Growth	472.00
	TOTAL	$ 1,767.01 million

About one-half of the funds provided by this legislation is to benefit displaced military and civilian employees of the Department of Defense (DoD); Of that, the majority is for various forms of jobs training and rehabilitation. Given the current national unemployment rate it is not clear for what sorts of jobs these displaced persons would be trained.

The $880.8 million of Title IV funds are for RDT&E line items considered by Congress to have potential commercial applicability. To facilitate this part of the reinvestment program the Technology Reinvestment Project (TRP) has been established as an interagency program involving: the Advanced Research Projects Agency (ARPA), the Department of Energy/Defense Programs (DOE/DP), the Department of Commerce's National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the National Aeronautics and Space Administration (NASA). The TRP is administered by the Defense Technology Conversion Council (DTCC), chaired by ARPA. The TRP Program Information Package indicates that $471.6 million of the $880.8 million FY-1993 Title IV Appropriations (RDT&E) are available for TRP projects. There is a 1.5 percent set-aside for the Small Business Innovative Research (SBIR) program. Three statutory requirements are common: (1) all programs require competitive awards, (2) all contain certain participation and organizational requirements, and (3) all anticipate cost sharing of at least 50 percent.

On February 23, 1994, the Director of Defense Research and Engineering announced the final 50 proposals selected under the FY-1993 Technology Reinvestment Project (TRP). This brought the competition totals to 212 proposals involving 1,631 organizations for a total of $650 million in Federal funds. The announcement noted that all funding will be at least matched by the participants. More than 2,800 proposals were submitted and subjected to an "exhaustive review process."

The Administration plans to continue the TRP in FY-1994-95, investing $150-$175 million of the FY-1994 appropriation on five to seven focused technology areas to be announced in March. The balance of the FY-1994 appropriation and a portion of the expected FY-1995 appropriation will be allocated to a competition to be announced this summer.

In reality, there is not much new here. The RDT&E budgets of prior years have

contained very similar, if not identical line items, available for industry to bid on. The SBIR program has also been in place for some years. Congress has painted old programs with a new brush to give the appearance of responding to the conversion challenge. More money will be spent on bureaucratic oversight.

President Clinton's Economic Plan proposed spending $20 billion over the next five years to facilitate conversion. Whether such outlays will produce the desired results is certainly open to question.

In a November 1991 "Report to Congress on the Defense Industrial Base," DoD indicated the intent to rely on free market forces to guide the restructuring of the industrial base. The DoD stated that the ability to meet national security needs would depend on the ability of industry to switch back and forth from defense to commercial production as required.

In commenting on this intended DoD approach, the General Accounting Office (GAO), in a March 1993 report, "The Defense Industrial Base" (GAO/NSIAD-93-68), strongly questioned its viability. The GAO noted that many defense companies "lack the experience and specialized knowledge to shift to commercial production and compete successfully in commercial markets." They noted further, that to the extent companies did not make the transition and failed they could be lost from the defense industrial base.

More recently, the Los Angeles Economic Roundtable report "Technology and Jobs, Defense Conversion in the Los Angeles Area," dated February 28, 1994, reported on the results of an industry survey. The thrust of the survey was to determine how the aerospace/defense firms in the region evaluated their dependence on defense contracts, how they saw the role of government in responding to the economic impacts of defense cutbacks, and what sorts of programs were needed. From the 358 respondents there were seven major findings:

- Share of revenue from defense business grew from 59 percent in 1991 to 65 percent in 1993. This was attributed in large measure to decline in civil aircraft sales — the significant nondefense portion of sales for this group. Conversion efforts had not opened up significant new commercial markets.

- Defense conversion is important to the region's future.

- The business community is "overwhelmingly critical of efforts by every level of government to respond to defense cutbacks."

- The majority of respondents is luke-warm about collaborating with government or other firms .

- Most firms want a stable regulatory environment, availability of financing, and information about new markets.

- The respondents showed the greatest interest in strategies involving independent growth and diversification.

- The firms were generally optimistic about their future but acknowledged that they had not had a good record in predicting their own growth or decline.

The technical and managerial capabilities in the defense industry are without question. The industry also owns impressive laboratory and production facilities, indeed an impressive and valuable national resource. If it is no longer needed at full strength, what should be done?

The answer is: It should, in part, be replaced — not converted. We should not try to put commercial work in General Dynamic's Electric Boat Division or in FMC's Ground Systems Division. These are representative of the many highly specialized operations now responsible for defense programs. They, and others like them, are still required in the defense industrial base that, because of inadequate government policy planning, has already been badly eroded in some critical specialties.

The preferred role of government is to continue the effort to ensure a generally healthy, expanding economy, and, as noted above, simplify and stabilize the regulatory environment.

In such an economic environment the provision of venture capital is much more likely to produce viable new commercial business enterprises, and expand the economy, than is a federally funded and bureaucratically planned technology development program. Some ventures will fail; some will succeed — that is fundamental to the strength of the free market system. The history of our economic development vis a vis that of the former Soviet Union should remove all doubt about that principle.

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DEFENSE CONTRACTING BUYER-SELLER RELATIONSHIPS: *THEORETICAL APPROACHES*

Lieutenant Colonel Carl R. Templin, USAF

This article examines the applicability of three theoretical approaches to defining defense buyer-seller relationships. Economic Free-Market Theory explains the relative economic power of the participants but ignores the legal, political, and socioeconomic aspects so pervasive in defense acquisitions. Transaction Cost Economics provides a framework for determining the most cost-effective type of contract governance for each transaction. Systems theory explores the degree of interdependence between the buyers' and sellers' systems. Each theory contributes unique insights into defense buyer-seller relationships that can be used to judge the appropriateness of contracting laws, regulations, policies, and management approaches for specific acquisition environments.

INTRODUCTION

Appropriate theoretical perspectives are needed if defense buyer-seller relationships are to be properly understood and managed. Theoretical models enable managers to understand why participants in the contracting process behave as they do and to define the complex relationships that exist. Theory is needed to understand how buyer-seller relationships should best be governed, to test the effectiveness of those management efforts, and to compare defense and non-defense related research streams. Such a theory will facili-

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tate the appropriate use of private sector management practices while avoiding those which are not appropriate.

This article explores three theoretical approaches. First, it examines a traditional free-market approach based on economic theory which focuses on the operation of market forces and the relative economic power of the participants. Next, a transaction cost economics approach is considered. It draws from economic and organization theory to describe the contractual relationship of the buyer and seller. Finally, a systems approach is used to describe the buyer and seller as separate, but interrelated systems. A brief description of each theory and its application to the defense contracting environment follows.

A MARKET APPROACH

One way to define the defense contracting buyer-seller relationship is in traditional economic terms with market forces operating to determine the price and quantities of the goods and services that are bought and sold. A perfect market (or perfect competition) exists when (1) the product is homogeneous in nature; (2) there are large numbers of buyers and sellers; (3) there is freedom of entry and exit for the sellers; (4) buyers and sellers have perfect

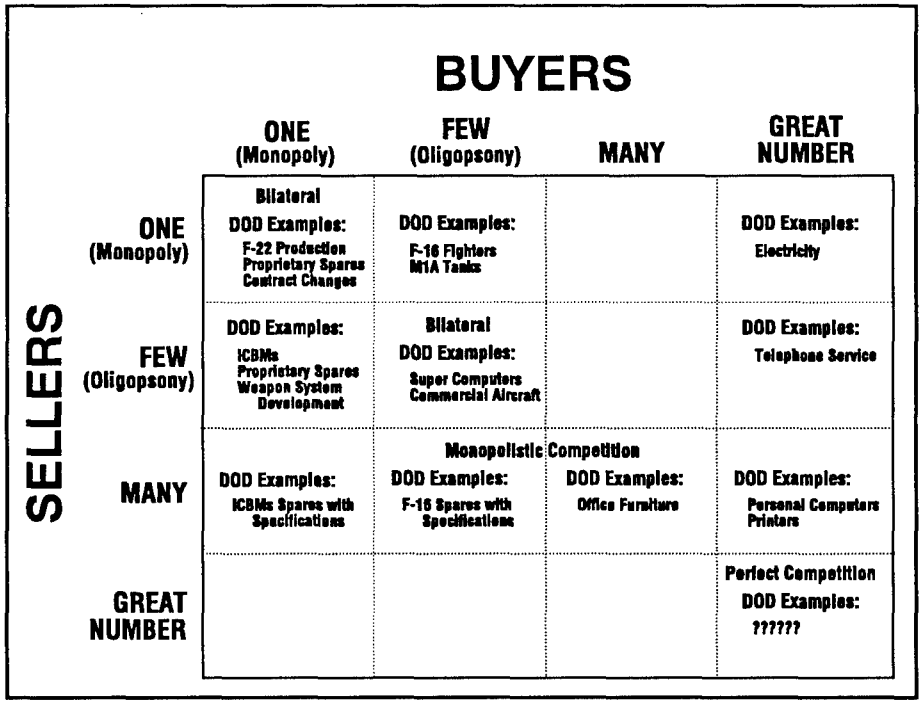

Figure 1. **Grid of Economic Market Relationships**

information/foresight with respect to prices; (5) the sales/purchases of each seller/buyer are insignificant with respect to the total volume of transactions; (6) no collusion exists among buyers and sellers; (7) consumers maximize total utility and sellers maximize total profits; and (8) the commodity is transferable (Pearce, 1986, pp. 190, 285-286). When one or more of these conditions are absent, the market is imperfect to some degree. If the product is not homogeneous, but product differentiation prevails, sellers have increased influence over price and monopolistic competition prevails. As the number of buyers or sellers decrease, parties can exert greater influence on the market and conditions of oligopsony/oligopoly or monopsony/monopoly prevail, as depicted in Figure 1.

Applicability to DoD

To the degree the federal government sets aside its sovereignty and acts on equal footing with private sellers, the defense buyer-seller relationship could be defined in terms of the economic power the buyers and sellers exert over each other. In such cases, the government could be said to be operating at some point on the grid in Figure 1. When DoD buying agencies enter the marketplace to buy commodities or commercial items, they rely on competitive market forces to determine the price. This would hold true for buying such things as office supplies and equipment. As the government's needs become more and more DoD unique, such as buying strategic missiles or nuclear warheads, DoD takes on the characteristics of a monopsonistic buyer. At the same time, the number of sellers also decrease, although for some weapon systems (such as tactical missiles) and spare parts, there exists a certain amount of competition. When research and development or weapon system production is involved, competition is frequently reduced to one or a few sellers. At the extreme, with one buyer and one seller, a bilateral monopoly exists. Even when competition is used at the outset of an acquisition, when contract changes are required, the contractor has monopolistic power in the ensuing negotiations, unless the government is willing to terminate and recompete the acquisition.

A market approach in defining defense buyer-seller relationships is advantageous in that economic theory provides a language that is well recognized and understood. There is also a rich body of economic theory and research to draw upon. The defense contracting literature is couched in economic terms and premises underlying our contracting regulations are, rightly or wrongly, founded on economic market theory to a large degree. However, economic market relationships are only one aspect of the defense contracting buyer-seller relationship. The government's sovereign power, the unique nature of defense acquisition, and the role of politics limit the appropriateness of using economic market theory to describe the defense buyer-seller relationship in a comprehensive way.

Sovereignty

The government does not completely lay aside its sovereignty. As a sovereign power, the government makes the rules with which all participants must comply. For example, it reserves for itself the right to unilaterally change the contract, force continued performance, or to terminate the contract at its pleasure. It can force sellers to disclose cost and technical information that is normally considered proprietary. It maintains the right to audit and inspect the sellers' records and internal operations. It can also force government standards on the sellers' operations as conditions for selling to the government. Thus, the sovereign power of the government makes it a very unique customer and gives it considerable power beyond the economic power that market forces alone would give it.

Unique Nature

The very nature of defense acquisition tends to violate many of the underlying assumptions of market theory, especially when contracting for DoD unique requirements. Peck and Scherer (1962, pp. 57-62) concluded that "a market system in its entirety can never exist for the acquisition of weapons" due to (1) large capital requirements that largely preclude private financing, (2) unique uncertainties associated with weapons acquisition (changing threats, strategies, politics, technology, etc.), (3) the buyer's role as the specifier of weapon systems, and (4) the fact that pricing is largely based on anticipated or incurred costs rather than competition.

Researchers have observed that defense acquisition tends to substitute administrative control mechanisms (such as auditors, quality assurance representatives, government standards, etc.) for market mechanisms (Peck and Scherer, 1962; Fox, 1974; Scherer, 1964). Fox (1974) and Gansler (1980) found extensive differences between the conduct of the defense and industrial markets, especially in terms of cost-based, rather than market-based pricing; the tendency toward a monopsonistic buyer; and a limited number of suppliers. Gansler (1980) also cites extensive barriers preventing firms from entering the defense "market" and inhibiting large defense contractors from exiting. Such barriers include requirements for highly specialized equipment, engineering, and scientific resources; unique reporting, accounting, quality, and purchasing systems; extensive regulations; erratic and relatively inelastic demand; plus other DoD-unique requirements necessary to do business with DoD but which are not useful or transferrable to the commercial/industrial sectors.

These barriers make it difficult for commercial firms to navigate the maze of contracting procedures to effectively compete for government contracts even for commercial type requirements. Thus, the very nature of defense acquisition tends to violate many of the assumptions associated with a free market, especially those relating to the number of buyers/sellers, their influ-

ence on price/demand, and the freedom of market entry/exit.

Political Forces

Finally, one must consider the political nature of the defense acquisition process, especially as it relates to Congress' role in overseeing and managing the budgetary and acquisition processes. Congressional authorization of programs and appropriation of funding generate considerable political overtones. Gansler (1980, 1989) and Fox (1988) point to such political factors as major causes of program instability, cost growth, and overregulation leading to inefficiency and waste. Adams (1982), examining the relationship between Congress, DoD, and defense contractors, found that defense contractors engage extensively in politically oriented activities (i.e. personnel transfers to/from government service, political action committees, lobbyists, trade associations, etc.) to influence the process to their benefit. His research suggests political forces can impact the contracting process and the buyer-seller relationship and thus cannot be ignored, especially when high dollar weapon systems are involved.

Alternative Economic Models

The nonmarket nature of defense acquisition has prompted researchers to suggest alternative economic models. Kaitz (1984) and Peterson (1987) suggested defense industries producing weapons should be regarded as regulated industries, rather than participants in a free market. Economic theory related to regulated monopolies could provide a useful model, although one must recognize that the consumer, the buyer, the regulator, and resolver of disputes are one and the same when defense acquisition is concerned. Kaitz (1984) also suggests welfare economics provide a better explanation into the nature of the defense market than traditional free-market theory.

Except for the simplest of defense acquisitions, traditional economic market theory, by itself, is not sufficient to capture the complexity of the defense contracting buyer-seller relationship, although it can provide some insight into the economic power wielded by the buyer and seller. The next section describes a theory that uses economic and organizational theory to focus more extensively on the contractual relationship between buyers and sellers.

A TRANSACTION COST ECONOMICS APPROACH

Transaction Cost Economics (TCE) matches business transactions with appropriate contractual governance structures that take advantage of production economies that may be available while minimizing transaction costs as much as possible (Williamson, 1979). Transaction costs are associated with "drafting, negotiating, and safeguarding the agreement" as well as costs associated modifying the agreement and resolving disputes and other postaward problems (Williamson, 1985, pp. 20-21). The range of governance structures

include total reliance on a competitive market (such as the use of sealed bidding or awarding contracts without discussions) on one extreme and performing the transaction entirely in house (such as government arsenals or depot repair facilities) at the other extreme. In between, contracts between the buyer and seller are used with varying levels of reliance on markets, negotiators, courts, and formalized contract administration and control mechanisms.

In order to select the best form of contract governance, two important behavioral assumptions and three transaction characteristics must be considered.

Behavioral Assumptions

The first behavioral assumption is *bounded rationality.* Individuals intend to act rationally but are limited in their capacity to solve complex problems and process information (Williamson, 1985) That is, individuals generally cannot anticipate and plan for all possible contingencies that may occur after contract award. Otherwise, they could include contractual provisions deal with all possible contingencies. Another problem is that some people resort to *opportunistic behavior* and are willing to deceive, steal, and/or cheat to gain greater benefit from a transaction. Incomplete or misleading information is a major TCE concern. Without the threat of opportunism, the parties of a contract could just trust each other to be fair and not take advantage of the other, regardless of any required changes. When such levels of trust are not prudent, the parties of a contract must find ways to protect themselves from dishonest behavior in all its forms (Williamson, 1985).

Transaction Characteristics.

According to Williamson (1985), there are three principal dimensions that characterize transactions. The first, and most significant dimension is *asset specificity*, which refers to the degree that special purpose investments (such as sites, physical and human assets, dedicated assets, etc.) are required for the transaction. The more highly specialized assets are, the less they can be converted to other uses and are subject to considerable risk should the transaction fail. For example, a contractor's plant dedicated to the production of strategic missiles uses assets that could not be converted easily to commercial uses.

The second dimension is *uncertainty*, which refers to unanticipated problems or those arising from opportunistic behavior, such as one party taking advantage of events that require contractual changes to improve its position at the expense of the other party. Uncertainty increases in importance when asset specificity is involved due to the high risk associated with highly specialized assets.

The third dimension is *frequency* of transaction occurrence. The costs

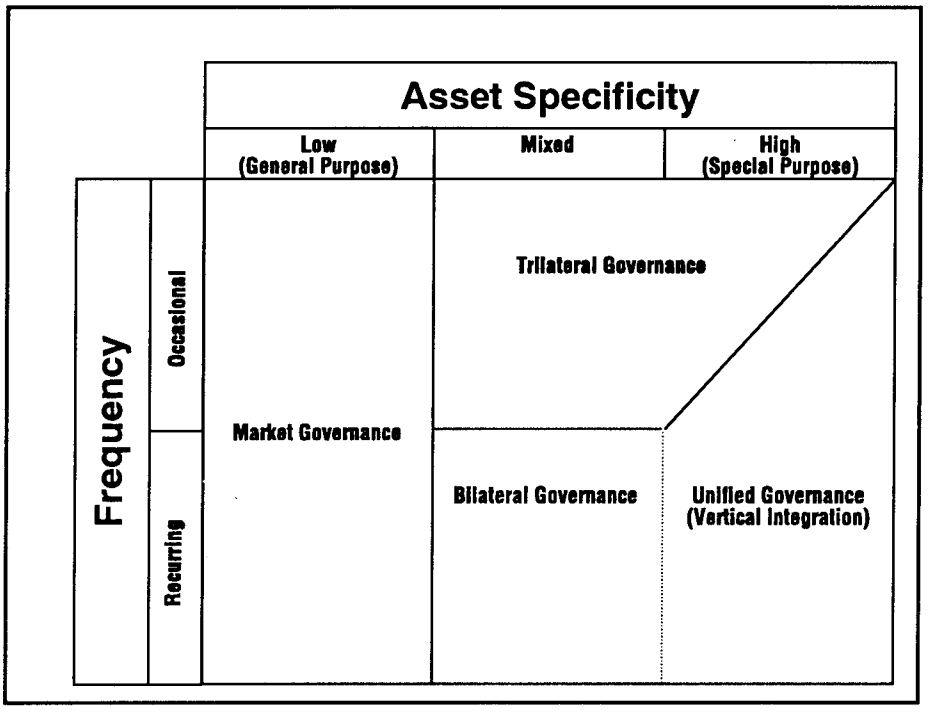

Figure 2. **Appropriate Governance.** Adapted from Williamson, *Economic Institutions*, p. 79.

associated with specialized governance structures are more easily justified when transactions are recurring in nature, rather than being a one time buy.

SELECTING THE BEST GOVERNANCE STRUCTURE

The best governance structure is one that can adapt to changes arising from bounded rationality while protecting the parties against the risks of opportunistic behavior. Assuming the presence of uncertainty, bounded rationality, and opportunism, the appropriate governance structure depends on the level of asset specificity and the transaction frequency, as depicted in Figure 2.

The competitive marketplace is most efficient when general-use assets are required, regardless of transaction frequency. Parties to the transaction rely on competitive market forces to protect each other from opportunism. If one becomes dissatisfied, the relationship is terminated in favor of another supplier (Williamson, 1985). When highly specialized assets are required, especially for recurring transactions, the transaction can be performed internally (vertically integrated) because the buyer can achieve the same economies of scale as the supplier, can more easily make changes, and can reduce transaction costs, since only the buyer's organization is involved. However, bureaucratic problems associated with the buyer's internal organization miti-

gate these benefits somewhat.

In between these polar alternatives are intermediate governance structures which are more efficient when a mix of specialized and general purpose assets are required. As asset specificity increases, the buyer and seller become more dependent on, and therefore committed to each other and the transaction. The supplier is more committed because alternative uses for its specialized assets are limited; the buyer's commitment increases due to higher costs associated with changing sources. Both benefit by maintaining the relationship, however, the hazards of opportunism grow because parties are in position to take advantage of one another. Mechanisms must be found to facilitate change while protecting against opportunistic behavior (Williamson, 1985).

Frequency of occurrence impacts the affordability of the contract governance structure. Williamson suggests a *trilateral governance* structure is most efficient for transactions involving mixed or highly specific assets but whose frequency of occurrence does not warrant the costs of establishing a specialized governance structure. In such cases, arbitrators or mediators are used to settle disputes that cannot be settled by the parties themselves. When transactions are recurring enough to warrant a specialized governance structure, *bilateral governance* is warranted. Problems associated with contract changes and opportunism must be addressed, either through automatic or routine contract adjustment provisions (such as economic price adjustment clauses, options, incentives, liquidated damages, etc.) or through predetermined means of resolving disputes.

One way to diminish the need for special contract administration provisions, and therefore costs associated with them, is the creation of *credible commitments* (transaction specific investments, posted bonds, reciprocal arrangements, etc.). In such cases, the parties provide "hostages" which make the relationship self-enforcing. For example, if executed properly, a warranty could serve as a hostage to motivate the contractor to make a quality product and lessen the need for the buyer to impose quality controls or inspections. The use of bid bonds and performance bonds are often used in a similar way to guarantee the reliability and performance of the seller.

Applicability to DoD

Williamson's theory appears to be applicable to defense contracting. Its underlying behavioral assumptions are relevant. The complexity and uncertainty associated with defense contracting suggest bounded rationality is an appropriate assumption. In addition to technical, schedule, and cost risks associated with the development, production, and support of complex, state-of-the-art weapon systems, changing technology, threats, defense budgets, political forces, economic forces, etc., create an ever changing climate that is impossible for the human mind to fully comprehend. Numerous ethics and

conflict of interest laws, disclosure requirements (such as the Truth in Negotiations Act), and the armies of auditors and investigators involved in the Federal contracting process attest to the presence (actual, perceived, or feared) of opportunistic behavior in the defense contracting environment.

Defense contracting generally follows the contracting pattern described by TCE. Competition for fixed-price contracts are used for products requiring standardized equipment, where uncertainty is not too great. If the production efforts require more specialized assets and involve greater uncertainty, negotiated bilateral contracts are used and administrative control mechanisms are substituted for market mechanisms. In a few cases, the government chooses to operate government owned production arsenals or depot repair facilities (such as depot maintenance of combat aircraft) rather than contract for those operations in the private sector. However, it generally relies on bilateral contracts with private industry to obtain its weapon systems and spare parts. Concerning the suggestion that only recurring transactions can support such a highly specialized governance structure, Williamson states the following:

> Defense contracting may appear to be a counterexample, since an elaborate governance structure is devised for many defense contracts. This reflects in part, however, the special disabilities of the government to engage in own-production. But for that, many contracts would be organized in-house. Also, contracts that are very large and of long duration, as many defense contracts are, do have recurring character. (1985, p. 73 footnote 1)

To some degree, the government uses credible commitments to reduce the level of administrative controls. For example, when contractors invest in a government-approved purchasing system, DoD relaxes its requirements for subcontract approval. However, in some cases the government insists on credible commitments without relaxing its level of control. For example, DoD frequently requires the contractor to provide warranties and use government-approved quality systems but still conducts duplicate government quality inspections. To the degree the contractor can show its system produces quality products, continued government surveillance incurs transaction costs without benefits.

Transaction Cost Economics provides a good theoretical base for understanding defense contracting buyer-seller relationships, especially in regard to the level of government control that is incorporated into the contracting relationship. It provides a framework for assessing the appropriateness of the contractual governance structure employed, given the characteristics of the transaction (especially asset specificity and uncertainty). For example, relying on competition and "market" controls for weapon system development and production is questionable, especially when extensive changes are likely

to occur after award or when cost reimbursement contracts are involved. It also provides a structure for assessing the level of credible commitment provided by the contractor and the level of related government control mechanisms.

Since TCE defines the buyer-seller relationship in light of governing contractual control mechanisms, it captures relevant economic and organizational issues of the relationship and is applicable even if the buyer has sovereign power and can impose controls over its suppliers. The next section uses general systems theory for defining how the government and defense contractor systems impact one another.

A SYSTEMS APPROACH

One way to better understand the buyer-seller relationship and the impact defense contracting requirements have on the contractor's operations is to examine the relationship as two linked systems. General systems theory can be used to focus on the linkages that exist between the buyer and the seller and how the two systems interact with each other. Churchman (1968) suggested the systems approach, used by scientists to study and comprehend scientific phenomena, could be effectively applied to the study of government, business, industry and human problems. Ashby (1960) showed how systems can be fully joined so that one system reacts mechanistically to disturbances from the other or how independencies can be achieved so that the system reacts only to selective disturbances. Glassman (1973) defined how the degree of coupling between living systems affects stability.

Relatively independent, or loosely coupled systems tend to have fewer variables in common or share weaker variables. Changes in one system therefore do not seriously impact the other. However, when systems are closely linked together, sharing many and/or stronger variables, changes in one system significantly impact the other. Loose coupling can be maintained actively, such as when the system defends itself against disruptive influences; or passively, such as when a system insulates itself such that it only responds when variables gain limited access. Glassman (1973) and Weik (1976, 1979) extended these concepts to organizational systems.

In order to determine the degree of coupling between the buyer and the seller, the number and strength of the variables connecting them must be identified. Landeros and Monczka (1989) applied systems theory to defining buyer-seller relationships. Three types of relationships were defined. A loosely coupled relationship is one in which the relative independence of the parties is maintained through open market bargaining. Contracts are frequently competed, generally based on a strategy of seeking lower prices. Both buyer and seller maintain a level of independence. Buying firms may attempt to insulate themselves from supplier disruptions through multiple sourcing and safety stock inventories. A tightly coupled relationship involves cooperative, buyer-

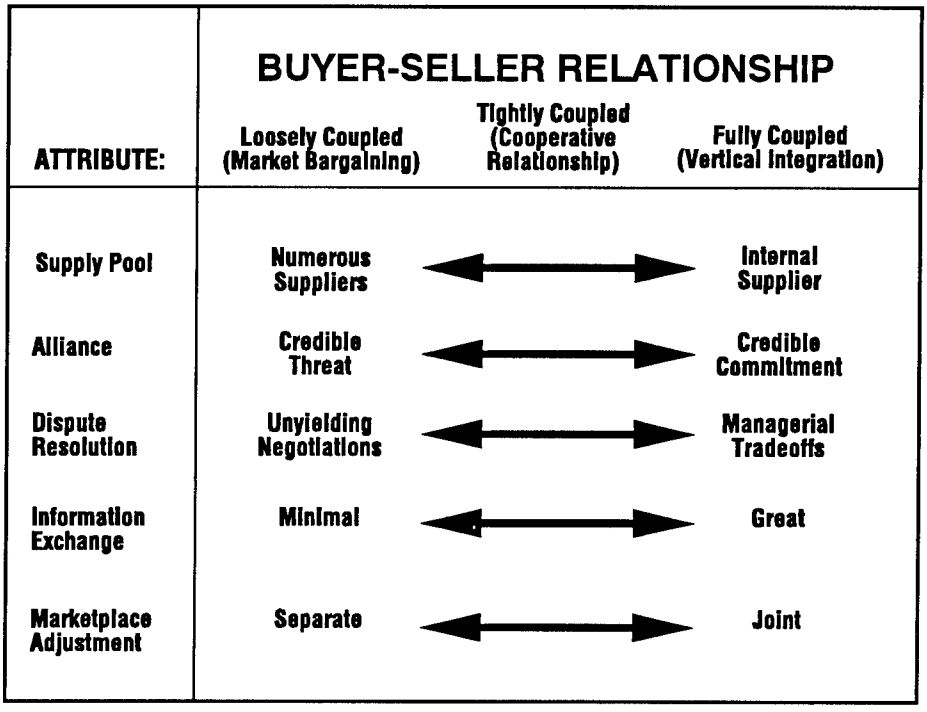

Figure 3. **Buyer-Seller System Coupling**
Source: Adapted from Landerous & Monczka, 1989, p.13.

seller relationships, designed to achieve mutually beneficial long-term, strategic goals, such as reducing total costs, better product performance, greater levels of quality, timeliness, and reliability in the flow of supplies flowing between suppliers and customers. Close buyer-seller relationships imply considerable interdependency and therefore a high degree of cooperation. A fully coupled relationship is analogous to backward integration with the source of supply internally integrated within the organization. Here, the buyer and seller are fully joined so that they now operate as one system.

Figure 3 illustrates these relationships in terms of five components which can be used to determine the degree of coupling in a buyer-seller relationship: (1) the number of suppliers in the supply pool, (2) the amount of credible commitment, (3) the manner in which disputes are resolved, (4) the flow of communication, and (5) the manner in which the two parties adjust to marketplace conditions.

Applicability to DoD

This model can generally be used to describe the level of interdependence between the government and the defense contractor, especially in terms of

the supply pool and information exchange. The Competition in Contracting Act has greatly increased the government's use of competition, and thus a move toward more loosely coupled relationships. This is especially so when there are numerous suppliers available. By and large, this is especially so at the middle and lower tiers of the defense industrial base where subsystems, spare parts, and materials are acquired. Where competition is less possible, such as in the production of a major weapon system, both parties tend to be committed to each other, resulting in a tighter coupling.

The information exchange between the government and the contractor can vary substantially. During a competitive awarding process, especially when sealed bidding is used, communication prior to award is strictly controlled. After award, communication is usually minimal and is limited to contacts with the buying and administrative office personnel, especially contract surveillance, quality, and transportation representatives. For negotiated contracts for complex systems, communication is extensive before and after contract award. Such contracts are also characterized by extensive communication with multiple functional representatives such as program managers, engineers, and technical representatives, in addition to the normal contracting officer's representatives. Thus, the amount of communication also describes the degree of coupling in a defense contracting environment.

The alliance between DoD and its contractors is generally considered to be at arms length and even adversarial. Still, use of credible threats and credible commitments varies. In many cases, the DoD modus operandi is the use of credible threat. When multiple sources are available, it uses threats of competition and termination to encourage contractor performance. When competitive sources are lacking, DoD withholds progress payments, threatens development of alternate sources to get leverage with the contractor. When DoD is coupled tightly to contractors, such as with developers of large weapon systems, credible commitments are more likely to be made. These include multiyear contracts, out-year options, provision of government-owned equipment/facilities, etc. Threats of termination or competition are much less noticeable.

As suggested earlier, contractors also make credible commitments, such as investment in DoD unique equipment, specialized expertise, and DoD approved systems. Such investments tend to lock contractors into the defense industrial base. The Government may reward them with less Government oversight.

The other two components may not be as applicable as in the private sector. Dispute resolution in government contracting is a fairly standard and formalized process, consisting of submission and negotiation of claims followed by appeals to boards or courts, if necessary. It is uncertain whether DoD is more accommodating to large prime contractors than to small ones. This would warrant some investigation. Market place adjustment is some-

what problematical since DoD requirements are driven by defense needs and congressional appropriations. As these requirements change, they are immediately passed on to defense contractors in the form of a change in the frequency and size of contracts awarded or, if current contracts are affected, by change notices, schedule changes, terminations, etc. and settlement costs are determined by negotiation or disputes.

For large weapons programs, there may be some joint resolution activities but for the most part, contractors are left to cope with changing demand and conditions on their own. This does not mean that these components are not applicable to defense contracting. Rather, they are not as useful in defining the contracting relationship as they might be in the commercial sector.

Such a systems approach concentrates on how tightly the buyer's system is joined to the seller's system. In the government's case, fewer available suppliers, greater communication, and strong commitments to each other would signal tighter coupling between the defense contractor and the government. According to the systems theory described above, a tightly coupled defense contractor would be subject to greater government influence and control over its internal operations than a more loosely coupled contractor. This is consistent with Gansler's (1989) research that suggests prime contractors facing limited competition, requiring extensive negotiation during the award process (or for subsequent changes), and whose factors of production are highly specialized toward defense production face extensive government controls. The opposite holds for contractors producing stable products with extensive competition, requiring little negotiation or communication, and using less specialized factors of production.

CONCLUSION

Each of the theories presented here provided distinct insight into the defense contracting buyer-seller relationship.

Economic theory as applied to markets is important to understand how the defense contracting environment is different from the traditional concept of markets. It is useful for gaining insight into the economic power of the buyer and seller. However, one cannot underestimate the importance that politics and sovereignty have in the defense contracting process.

Transaction cost economics provides a more useful theory for defining the nature of the contracting relationship between the government and defense contractors and the regulatory aspects of the administrative controls the government uses to protect its interests against potential opportunistic behavior by participants in the process. It provides a model that is useful for the full range of contractual relationships ranging from the use of competitive, firm-fixed-price contracts using a quasi market governance mechanism to cost reimbursable contracts with extensive administrative control mechanisms.

Finally, systems theory helps to explain the interrelationship between the

government and the defense contractor as two linked systems. It is especially useful to describe how the government's controls and requirements impact the internal operations of the defense contractor and how the performance of the defense contractor impacts the government.

The important issue is not whether one particular theory can or cannot capture all the intricacies of the defense contracting buyer-seller relationship. Rather, that each provides a unique theoretical perspective that can be used, either individually or in concert with other theories, to focus on the particular issues of interest. Theoretical perspectives open up a vast amount of non-defense literature that can be used to better define and understand the buyer-seller relationships operating in the defense environment. The common features between non-defense and defense buyer-seller relationships can be explored and understood while at the same time recognizing the unique differences.

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FACTORS AFFECTING NEW PRODUCT DEVELOPMENTS

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Fourteen commercial and 13 Department of Defense (DoD) new product developments are reviewed and analyzed to understand the factors responsible for reducing development times. The major groupings of factors affecting new product developments were found to be the extent and character of functional interactions, disciplined product development techniques and methods, development process adaptations and to a limited extent capital investments.

INTRODUCTION

As U.S. industry faces increasing world competition following the end of the Cold War, the United States must be extremely quick in product developments to stay ahead of other world competitors. This is a view shared by Arnold Putnam (1985, p. 139) who says,

> Investing in new technology will not alone ensure the competitiveness of U. S. industry. Things have to be run right, and processes must be efficient. Industry must do its job correctly and quickly. Despite the investment and attention it has recently given to manufacturing, American industry is still slower to market than some of its foreign competitors, and the final product often has many defects.

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Every day we see examples of how foreign products capture U. S. market share. Examples of differences in product developments between U. S. and Japanese companies are given in Table 1. However, the United States has not always lagged the world in speedy new product developments. During and after World War II, several new developments were accomplished in record time: the North American P-51 Mustang in 120 days, the Lockheed "Skunk Works" P-80 jet in 143 days, and the 1955 Chevrolet in two years. But, over the past several decades America has lost two-thirds of its machine tool industry and one-third of its automobile industry market share (Ziemke & Spann, 1991).

In numerous instances competitors have garnered market share by being faster to market. In the Boeing-pioneered wide body aircraft market, Boeing lost 50 percent of its wide body aircraft orders because Airbus Industrie came to market several years earlier with its A-300 model than Boeing's comparable Boeing 767 model (Ziemke & Spann, 1991). United Research Co. of Morristown, N.J., found that 6 out of 10 chief executive officers (CEOs) see shortening of the design and manufacturing cycle as the critical factor to

Table 1.
TIME VARIANCES BETWEEN JAPANESE AND U.S. PRODUCT DEVELOPMENT CYCLES

TYPE OF PRODUCT	JAPAN	U.S.
Aircraft (concept to delivery)[a]	6-7 yrs	12-14 yrs
Dies and Forgings (concept to production)[a]	1/2 U.S. time	
Office Automation Equipment[a]	1/2 U.S. time	
Automobiles (concept to delivery)[b]	24-36 mo	54-60 mo
Flexible Manufacturing Systems[c]	18 mo	30-36 mo

Sources:

[a] Clinton W. Kelly, III., and J. L. Nevins, et al, *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: Defense Advanced Research Project Agency (DARPA), 1989), 15.

[b] Kim Clark and Takahiro Fujimoto, "Overlapping Problem Solving in Product Development," Harvard Business School working paper 87-048, April, 1988, in *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: DARPA, 1989), 15.

[c] R. Jaikumar, "Post-Industrial Manufacturing," *Harvard Business Review*, (November-December 1986) in *Findings of the U.S. Department of Defense Technology Assessment Team on Japanese Manufacturing Technology* (Arlington, VA: DARPA, 1989), 15.

maintain market share (Rohan, 1990). Bringing products on-line faster has other benefits which could improve both the bottom line and long term competitiveness. According to Takeuchi and Nonaka (1986), company emphasis should be on new products as a source of new sales and profits. To support this assessment, Takeuchi and Nonaka state that 25 percent of 3M's sales is realized from products less than five years old. In addition, a 1981 survey of 700 U. S. companies forecasted that one-third of profits in the 1980s will come from new products whereas only one-fifth of profits in the 1970s came from new products (Fraker, 1984).

Many different industries seem to realize the importance of time to market. According to Earl Koops, the Ford manufacturing director, "Now that the quality gap has closed, time to market is where the competitive edge is" (Owen, 1992, p. 69). If a company can decrease the time it takes to develop new products, then it can pursue new strategies. Products can have shorter lives which allows the company to make more models or to cash in on the products at their optimum profitability.

If models are quick in development then deficiencies can be quickly corrected in future models. Panasonic uses such a strategy in consumer electronics where a vast number of models in each product line is put on the market in order to see which product sells before gearing production up to full volume (Reiner, 1989). In 1981 Honda, facing a challenge from Yamaha in the motorcycle market, successfully blunted that challenge by replacing or introducing 113 new models in 18 months compared to a 60-model line before the challenge. Yamaha could not keep up, and publicly pledged respect for Honda after this remarkable new product development display (Stewart, 1989).

We have a number of examples where rapid new product developments either reflect a more competitive market environment or determine a more competitive strategy. The machine tool industry, traditionally a more static product line, recently experienced a situation where 50 percent of their current products sold did not exist five years ago. A quick development cycle and intimate working relationship with processor supplier Intel gave Compaq Computer the market lead in the introduction of the DeskPro 386 Model with only a 6-9 month development time, compared to industry average of 12-18 months. In new cars, Honda took 2 years to develop a new model whereas GM took 5-6 years. Therefore, in 10 years Honda went through the new product development process five times compared to GM's two (Reiner, 1989).

Being able to introduce new products is a defensive and offensive strategy. Durivage Pattern and Manufacturing, Inc., of Williston, Ohio, eliminated their competition by producing molds for Pontiac within four months while their competitor took twice the time (Rohan, 1990). Therefore, the supposition that speedy new product developments are crucial to maintaining or

recapturing market share in the world marketplace is supported. How then can U. S. companies be world competitors through quick new product developments?

INVESTIGATION

In this article, I will investigate which factors most improve a company's ability to introduce new products speedily. Information was sought about government and commercial product developments to ascertain what was defined by the companies or various authors as key factors responsible for reducing new product development times. Where available, the reduced development time experienced was recorded. I picked 14 commercial and 13 defense industry companies for study. I evaluated each company to determine the factors which the author cited as key contributors to speeding developments, and then analyzed them to determine their relative strength in speeding new product developments in both commercial and defense product areas.

FINDINGS

In collecting data I found a number of different factors were cited as influential in reducing the cycle time. These factors are grouped into the following five major categories: functional interaction, interaction characteristics, product development techniques and methods, development process adaptations, and capital investments. Table 2 gives a more complete breakdown of these factors. I will equate functional interaction with the term "team." Interaction characteristics or team characteristics defined how the new product development teams themselves functioned. In the product development techniques and methods category, primary focus was on externally developed techniques or methods used by new product developers as a means of improving or expediting new product developments or production. In a number of new product developments, the companies modified their pocesses. I have assembled these development process changes under a development process adaptations category. Finally, a category of capital investments and major capital expenditures were linked to speeding product development or manufacture.

I investigated 27 products to determine the reason the product development was successful in decreasing the cycle time, and to establish an idea of the product development time reduction realized. Table 3 reflects the results of the investigation for commercial products, and Table 4 reflects the results for defense products. The reasons for success, as tabulated in Tables 3 and 4, are keyed to the factors by number and letter in Table 2. Only those factors mentioned as the reasons for reduced development time were tabulated. Analysis of the determinant for success can be instructive. Table 5 summarizes the individual factors which reduced the development cycle time, and Table 6 analyzes the major categories to determine rank order.

Table 2.
FACTORS WHICH REDUCE PRODUCT DEVELOPMENT TIMES

1. **Functional Interaction**
   a. **Design Engineering and Manufacturing**
   b. **Design Engineering, Manufacturing and Suppliers**
   c. **Design Engineering, Manufacturing, Marketing and Suppliers**
   d. **Design Engineering, Manufacturing, Marketing and Sales**
   e. **Design Engineering, Manufacturing, Marketing, Sales and Suppliers**
   f. **Design Engineering and Suppliers**
   g. **Multiple teams for each product**
   h. **Producibility, Reliability and Maintainability on team**

2. **Interaction Characteristics**
   a. **Collocation**
   b. **Small size**
   c. **Broadly experienced**
   d. **Team members trained or educated**
   e. **Team decision making allowed**
   f. **Guru as head of team**

3. **Product Development Techniques/Methods**
   a. **Statistical Process Control (SPC)**
   b. **Quality Functional Deployment (QFD)**
   c. **Design of Experiments (DOE) or Taguchi Methods**
   d. **Total Quality Control (TQC) or Total Quality Management (TQM)**
   e. **Just-In-Time (JIT)**
   f. **Factory layout changes**
   g. **Design for Assembly (DFA)**

4. **Development Process Adaptations**
   a. **Design rules**
   b. **Expert systems**
   c. **Attitude changes (including workforce training or education)**
   d. **Manufacturing process development overlapped with design**
   e. **Computer design tools**

5. **Capital Investments**
   a. **Automation equipment**
   b. **Computer Aided Design/Computer Aided Manufacturing (CAD/CAM)**

In the commercial products analyzed, there was no single predominant factor (as defined by having significantly more instances of being mentioned as compared to the rest of the factors). However, functional interaction factors were mentioned the most as the reason for reduced new product development time. In defense products, however, several predominant factors emerge. Engineering and manufacturing functional interaction as a factor (with a count of 9) lead followed by the computer design tools factor in process adaptations (with a count of 8). For defense products, the development process adaptations category contributed most to reducing the development process.

Table 3.
RESULTS OF INVESTIGATION INTO
COMMERCIAL NEW PRODUCT DEVELOPMENT TIMES

COMPANY	PRODUCT	DATE	CYCLE TIME REDUCTION	WHY
John Deere[a]	Combine & Log Skidder	1985	50%	1b,1g,2a,2e,3f,4c,4d
Vista Chemical[b]	Chemicals	1990		1d,4d
Chevrolet[c]	1955 Model	1955	80%	2b.2c
B. F. Goodrich[d]	Carbon Brake		67%	4e
Allen-Bradley Co.[d]			50%	1a
PTA Corp.[d]	Molds		50%	4e,5b
RCA[d]	TV Chassis		50%	1a,3f
Rogers Corp.[d]	Elastomeric		70%	1a,3f
Compaq Computer[e]	PC	1980	50%	1f
Fuji-Xerox[f]	Copier	1978	24%	1b,2a,3d,4d
Murcury Computers[g]	Processor Boards		28%	1c
Boeing[g]	Boeing 777	1990	50%	1e,4e
Hewlett-Packard[g]	Oscilloscope	1980	33%	1d,1h,3d,3g,4e
Cisco Systems[g]	Multiport Comm Board	1989		1e

Sources:

[a] Richard E. Anderson, "Strategic Integration: How John Deere Did It," *Journal of Business Strategy* 13 (July/August 1992): 26.

[b] Bob Isenhour and Kathryn Payne, "Getting Serious About Product Development," *Management Review* 80 (April 1981): 20.

[c] Ziemke, "Don't Be Half-Hearted," 47-48.

[d] Rohan, "In Search of Speed," 79.

[e] Reiner, "Winning the Race," 52.

[f] Takeuchi and Nonaka, "The New New Product Development Game," 141.

[g] Alfred Rosenblatt, ed., "Concurrent Engineering," *IEEE Spectrum* (July 1991): 22.

Table 4.
RESULTS OF INVESTIGATION INTO
DOD NEW PRODUCT DEVELOPMENT TIMES

COMPANY	PRODUCT	DATE	CYCLE TIME REDUCTION	WHY
Texas Instruments[a]	Micro-Electronics	1990	24%	1h,3a,3b,3c,4b,4c,4e 5a
ITT Corp.[a]	Electronic	1982-84	33%	1a,1h,2a,3a,3b,3c,4a 4c
IBM[a]	Masterslices	1980s	40%	1a,4a,4d,4e
Hewlett-Packard Co.[a]	Multiple		35%	1e,2d,3a,3b,3c,3d,3e 4c
Northrup Corp.[a]	Bulkhead		54%	1a,1h,3a,3d,4d,4e
Boeing Missle[a]	Missiles	1985		1b,1g,2b,2d,2e,3d,4c 4e
Grumman Corp.[a]	C-17			1a,2a,4e
McDonnell Douglas[a]	AV-8, T-45	1987		1a,1h,3a,3b,3c,4b,4c 4e
Raytheon Inc.[b]	Patriot	1985		1a,1h,4a,4e,5b
ITEK Optical[b]	Mirrors			1a,4c
Lockheed Skunk Works[c]	P-80	1943	20%	1a,2a,2b,2c,2e,2f
North American Aviation Corp.[d]	P-51 Mustang	1940		1a,2b,2c
Collins[e]	GPS		42%	4e

Sources:

[a] Robert I. Winner et al., *The Role of Concurrent Engineering in Weapons Systems Acquisition*, (Alexandria, VA: Institute for Defense Analyses, December 1988), 64, 71, 73, 80, 83, 87, 91, 95.

[b] Alfred Rosenblatt, ed., "Concurrent Engineering," 34-36.

[c] Ben R. Rich, Lecture, "The Skunk Works' Management Style," for Wright Brothers Lectureship in Aeronautics.

[d] Ziemke and Spann, "Warning: Don't Be Half-Hearted," 47.

[e] Rohan, "In Search of Speed," 79.

Table 5.
SUMMARY OF WHY CYCLE TIME WAS REDUCED

FACTORS	COMMERCIAL	DOD
1. Functional Interaction		
1a Engineering & Manufacturing	3	9
1b Engineering, Manufacturing & Suppliers	2	1
1c Engineering, Manufacturing, Marketing & Suppliers	1	0
1d Engineering, Manufacturing, Marketing & Sales	2	0
1e Engineering, Manufacturing, Marketing, Sales & Suppliers	2	1
1f Engineering & Suppliers	1	0
1g Multiple teams for each product	1	1
1h Producibility, Reliability & Maintainability on team	1	5
2. Interaction Characteristics		
2a Collocation	2	3
2b Small Size	1	3
2c Broadly Experienced	1	2
2d Team members trained or educated	0	2
2e Team decision making allowed	1	2
2f Guru as head of team	0	1
3. Product Development Techniques/Methods		
3a Statistical Process Control (SPC)	0	5
3b Quality Functional Deployment (QFD)	0	4
3c Design of Experiments (DOE) or Taguchi Methods	0	4
3d Total Quality Control (TQC) or Total Quality Management (TQM)	2	3
3e Just-in-Time (JIT)	0	1
3f Factory layout change	3	0
3g Design for Assembly (DFA)	1	0
4. Development Process Adaptations		
4a Design Rules	0	3
4b Expert Systems	0	2
4c Attitude changes (including workforce training & education)	1	6
4d Manufacturing process development overlap with design	3	2
4e Computer design tools	4	8
5. Capital Investments		
5a Automation equipment	0	1
5b Computer Aided Design Computer Aided Manufacturing (CAD/CAM)	1	1

In contrast, the commercial new product developments show more integration of the other functional interaction factors such as marketing, sales and suppliers as the reasons for success. In new defense product developments, the study results indicate less emphasis on multifunctional teaming as opposed to multiple discipline teaming where the "ilities" (producibility, reliability and maintainability) are the predominant team members. The highest count value for a single factor in commercial products was the use of com-

Table 6.
RESULTS OF WHY CYCLE TIME WAS REDUCED BY MAJOR CATEGORIES

	COMMERCIAL TOTAL			DOD TOTAL		
MAJOR CATEGORY	COUNT	PERCENT	RANK	COUNT	PERCENT	RANK
1. Functional Interaction	13	39%	1	17	24%	2
2. Interaction Characteristics	5	15%	4	13	19%	3
3. Production Development Techniques/Methods	6	18%	3	17	24%	2
4. Development Process Adaptations	8	24%	2	21	30%	1
5. Capital Investments	1	3%	5	2	3%	4

puter design tools. In defense products, the computer design tools factor did not have the highest single count, however, with strong support from the attitude changes factor, the development process adaptations category in total ranked first. Strong influence is indicated with a second order ranking from both the functional interaction and the product development techniques and methods categories. Therefore, defense product developments value the use of these quality tools and techniques more heavily than the commercial product category and mention them as often as factors in the functional interactions category as being responsible for speeding developments. The data indicates little difference between commercial or defense product categories regarding interaction characteristics and capital investments. Each mentions these factors relatively equally. Neither product area relied on capital investments for reductions to new product time. Overall, the degree of improvement in new product development time between commercial and defense developments is significant. Commercial products average a 50 percent reduction in development time as compared to 35 percent reduction for defense products.

OBSERVATIONS

Wheelwright and Clark (1992) use the terms upstream and downstream to describe the relative position of functional elements of an organization to the product development location at a particular time. Therefore, to them, upstream functional elements provide inputs to downstream functional elements. Traditionally, U.S. design engineers tended to develop the entire product

then "throw the design over the wall" to manufacturing for production. By doing that designers forfeit understanding manufacturing constraints and limitations, and manufacturing cannot easily influence improvements to the design to improve efficiency or yield.

This predicament can work in both directions. Service departments can "throw the service problem back over the wall" to design or manufacturing based on field feedback. As a new product develops, the upstream functional elements must be willing to share preliminary information with downstream organizational elements. Conversely, the downstream organizational elements must be willing to act on this early information or ideas. A certain risk exists in this arrangement. A mutual trust and commitment between these upstream and downstream organizational elements must develop. In the organization, teamwork and sharing must be valued as highly as technical competence and they must be open enough to tolerate mistakes as a learning process.

The overwhelming method used to share information across functional areas was through some form of teaming arrangement combining a number of key functional elements or disciplines. This functional interaction was variously described as concurrent engineering (CE), simultaneous engineering, integrated product development (IPD), or cross functional integration. This team forming need not be limited to the developing organization. A number of instances were seen where suppliers and even customers were active members of new product development teams.

However, just forming a project team was not enough. Other ingredients needed to be fostered. A key ingredient was communication between the upstream and downstream organizational elements that allows the integration of capabilities, the understanding of constraints and the understanding of risks. Communication was speediest and most effective when the various functions were collocated. The AT&T devised a 50-yard rule which stated communication among team members decreases by 80 percent when the members are more than 50 yards apart (Owen, 1992). Communications must be developed early in the project and lead to integrated problem solving.

To foster information sharing essential to speedy new product development, there must also be a management attitude which allows cross functional communication, tolerates trial and error learning, develops skills through training and education, and allows a degree of team autonomy in product development decisions. In Japan, the combination of these management attitudes coupled with the forming of design and manufacturing teams around a senior "guru" working as a united, interdepartmental group, is called "wa" (Ziemke & Spann, 1991).

Trust must be exhibited. Design functions must be willing to share preliminary information with manufacturing (and other) functions, and these downstream functions must be willing to act on this early information. Teamwork and sharing must be nurtured and valued as highly as technical performance

of the product. Trust is enhanced if the interacting functional elements are staffed with technically competent personnel. This product development approach using teamwork is not often taught in engineering schools; therefore, it must be supported by management and ingrained in the company culture. Risks exist in functional development teaming. If the team is ineffective, the management not fully supportive, or the project so mammoth that functional integration becomes unwieldy, then the benefits of functional teaming will not be realized. Putting together all the elements mentioned above is not easy. A key ingredient to success is management's ability to maintain visibility on the new product development and management support for the functional interactions.

Another area significantly affecting new product development was using computer design tools. Rockwell International's Collins Government Avionics Division designed the Global Positioning Satellite receiver to fit a tight, two-inch space in the Tomahawk missile using 3-dimensional computer aided design software in 14 months vice 2 years (Rohan, 1990). In other applications, design software facilitated communication between design and manufacturing personnel by forcing them to work together on the software design workstations. In another instance, a jet engine builder used a desktop manufacturing workstation to create prototype turbine blades in a few days as compared to their previous experience of 9 months (Rohan, 1990). In each of these cases, the new product development was shortened by time savings caused by using the software tool.

Tools to aid design or manufacturing make normal tasks faster. Particularly helpful was computer technology applied to paperless design and design aids. Incorporating algorithms to automatically do circuit layout, thermally analyze circuits, or incorporate expert experience greatly speeds the design process itself.

Another characteristic speeding new product development is the ability to do many functions in parallel, rather than serial order. Takeuchi and Nonaka (1986) provide the best simile when they compare the traditional serial approach to a relay race where one member hands the baton to another until the end of the race as opposed to the new concurrent approach similar to a rugby game where each team member passes the ball back and forth as needed to score. Such team allegiance allows information to flow effectively among the various functions so the product development ultimately can be compressed.

An area where work needs to be done is compensation and promotion of members of functional teams. Unfortunately this does not fit with most current compensation and promotion systems. Most companies compensate the individual, rather than seeking to maximize team performance. Actually, compensating the individual tends to create animosity between team members unless rewards are similar. A functional pecking order also hinders

equal compensation. Without resolving these policies, the positive aspects of teaming could be diluted because of real or perceived friction.

In addition to faster new product development, there were many other positive benefits that occurred as a result of promoting a concurrent design approach. General Dynamics (Jobe, 1992) ran a concurrent engineering project on a new Atlas payload adapter development. Results were:

20 percent reduction in design hours
45 percent reduction in span time
75 percent reduction in engineering changes
70 percent reduction in hands-on production hours
90 percent better first time quality

Similar results were obtained in other cases from reduced design iterations, reduced design complexity, shorter production times, and flatter learning curves in manufacturing. The following is based on findings of the Department of Defense Technology Assessment Team on Japanese Manufacturing Technology (Kelly, Nevins, et al, 1989):

The application of concurrent design within America has had surprising results. When used on 24 different products ranging from aircraft engine parts to outdoor lighting, it was found that part count was reduced by 30 percent on the average, and labor reduction for assembly operations resulted in a 44 percent savings. In another example, the design being released to production had 20 percent fewer parts and 40 percent less labor than would have otherwise been achieved had concurrent design not been used.

As noted above, there were significant improvements in product quality. For a faster new product development, the quality of the design and the manufactured items must be high to reduce time losing rework (either engineering change orders or product rework) and reduce costs. If everything is done right then it takes less time to do it. Cost savings were mentioned mostly terms of life cycle cost. Initial concurrent engineering costs are higher but the downstream costs are significantly lower when the impact of reduced engineering change orders and reduced manufacturing rework is considered. Not particularly transparent was the injection of innovation into new product developments. As long as the development team exercised design autonomy and was challenged by complexity or schedule, it often developed innovative solutions which saved time. The integrative aspects of the functional interactions aided in the innovation process. As long as management was not interposed in this integrative process, innovation was fostered.

CONCLUSION

Based on the results of the 27 new products investigated, it is apparent that a functional interaction involving manufacturing has significant positive im-

pact on accelerating product development times. Only one instance for speeding new product developments did not involve functrional interaction with manufacturing. In the functional interaction group the interaction between the upstream and downstream elements and the integration of competing design demands in the design process fostered rapid product developments.

Development process improvements are also significant in reducing product development times. Although this study suggests the degree of manufacturing involvement in product design has significant impact on reducing development time, it is not so simple. To be most successful in speeding developments, a company must simultaneously endorse four broad categories: a organizational wide functional team involvement, a supportive environment for team interaction, improvements to the development process, and the employment of useful product development methods.

Success can be achieved with improving the development process or employing proven development methods, but special benefit is derived from using schemes fostering functional interactions. My research indicates that communication fostered through the teaming arrangements across functional boundaries is the clay that molds all the elements together for a successful new product development. In the experiences of an integrated product development team at McDonnell Douglas Corporation, the following lessons learned support this conclusion: team collocation, team empowered to make decisions, focus on the product vice functional department, communication through team meetings, work to an integrated schedule, and concept validation and prototyping (Dutcher, 1991). There are other benefits as well. Not only will this four-pronged attack reduce development time, but it is reasonable to expect the development ultimately will cost less and be conceived more innovatively than if done in serial fashion.

Besides the employment of the above approach, a company should challenge the team with an aggressive goal, but not limit its means to accomplish that goal. The company should use subtle control as defined by Takeuchi and Nonaka (1986) to control the product development by: selecting the right people, creating an open work environment, encouraging engineers to learn from field and customer experience, establishing an evaluation and reward system based on group performance, managing the differences in activities during different phases of the product development, tolerating and anticipating mistakes, and encouraging suppliers to become involved. With this challenge and incremental reviews and performance trade-offs, the new product development has the best chance of being innovatively developed quickly with high quality.

The DoD recognizes that changes are necessary. The 1989 Technology Assessment Team on Japanese Manufacturing Technology report found that Japanese companies use concurrent engineering to better satisfy end-user needs, substantially reduce costs and development time, and ensure availabil-

ity of appropriate manufacturing means. As reported by Nicholas Torrelli (1992), the Assessment Team recommended to the DoD that the sequential design practices be replaced with streamlined concurrent practices reducing nonvalue added labor, allowing more design options, and simultaneously trading off issues of performance, producibility, supportability, quality and cost from the earliest phases of design. Effectively implemented, these recommendations can improve the new product development process and make the DoD a better customer.

The degree of improvement in new product developments is higher in commercial than defense products. The commercial world has integrated communication throughout its functional organization and its users as the primary means to improve development time. In defense products, there are institutional barriers hindering extensive functional integration. That is why I see more emphasis on discipline interaction and less interaction with customers and government overseers. Consequently, in the defense product area, I see a more predominant emphasis on development process and methods. This may also account for why the development time improvements lag the commercial product area. If DoD were allowed the freeway that successful commercial new product developers are enjoying the results might be just as dramatic.

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USING DATA TYPES AND SCALES FOR ANALYSIS AND DECISION MAKING

Dr. Richard Pariseau
Dr. Ivar Oswalt

As the selection among alternatives and allocation of scarce resources is increasingly subjected to critical review and public second guessing, the popularity of quantitative prioritization schemes is increasing. Most models applied properly with reasonable assumptions are effective and defendable. In the past, prioritization models were used with empirical data where accuracy related to measurement precision, but today models are being used with data that reflect subjective assessments of relative values in abstract terms. The scales used to "quantify" these assessments frequently do not conform to the data requirements of the model with respect to fundamental rules of data manipulation. It is not unusual to discover a quantitative prioritization scheme has serious flaws in its data scale. Program managers, decision makers and analysts must recognize the four fundamental types of data and data scales, and understand the numerical manipulations that can be performed with each type.

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DECISION MAKING ENVIRONMENT

The defense acquisition climate is one of decreasing budgets and increasing demand for available funds. Efficiency dictates that managers prioritize programs so that each budget cut will not require a new evaluation of options. Additionally, managers are frequently being required to justify their decision in selecting among alternatives both within their organization and externally. The consequence is the increasing use of quantitative decision analysis. New techniques are constantly being introduced, some have reached the stage of popularity that results in their mention by sophisticated decision makers at cocktail parties (TQM, COEA, QFD, AHP, etc.),[1] and most have software available for easy application. Also, the increasing demand and fashionableness of quantitative decision analysis, and the availability of software models, have spurned a misuse of data that must be corrected less the proliferation of erroneous results discredit the real potential of decision analytical methods.

Abstract assessments are inherently subjective because the "true value" cannot be measured conventionally. A subjective assessment is a fundamental attempt to derive "numerical" measurement from personal value. Numerical data can be divided into four categories, differentiated by the scale used to separate the numerical values, and consequently, the mathematical manipulations (and therefore the type of assessments) that can be performed with each kind of data. In increasing level of flexibility and robustness (i.e., more can be done with the last type), the four types of data and scales are: nominal, ordinal, interval and ratio.

Understanding the different data and scale types can save analysts significant grief, keep decision makers from making erroneous choices, and may even keep some program managers out of court. An example is recent ruling by the General Service Administration Board of Contract Appeals which upheld procurement protest because the Navy violated fundamental rules of data analysis and decision making. The details are discussed in this article.

NOMINAL DATA AND NOMINAL SCALES

As implied by the title, this type of data has been given *names* or *labels* (nominal, from the french "*nom*" = name). Nominal data can be counted, but no superiority or preference can be implied from the numerical value of the labels, and no arithmetic manipulations can be performed on the labels themselves.

The convention within the United States is to designate highways that lead generally in a north-south direction with odd numbers, and those that lead generally east-west with even numbers. This labeling convention is useful for

1 Total Quality Management (TQM), Cost & Operational Effectiveness Analysis (COEA), Quality Funciton Deployment (QFD), Analytical Heirarchy Process (AHP).

quickly recognizing the general direction of a numbered highway and for easily counting the number of north-south highways going through a state by quickly counting the number of odd numbered routes. This is clearly nominal data. The data (number of north-south highways) can be counted, but no superiority is implied by the numerical designations (route 95 is not better than route 5 nor worse than 101), and no arithmetic can be performed with the labels (route 101 plus route 5 does not equal route 106). Nominal data has no scale in the conventional sense that a higher number is superior to a smaller number.

In developing a technology investment strategy to combat the supply of illegal drugs, an analyst decomposed the process into hierarchical schema. The illegal drug problem results from the production, wholesale, retail distribution, and resulting generation of capital. The production process further decomposes into growing, harvesting, and processing. Wholesaling depends on transportation (from the producing country to the United States) and entry into the United States. The act of retailing depends on distribution of the drugs to the street vendors and the actual sale to users. The capital generated can be banked, laundered, or reinvested to continue the drug cycle. This hierarchical decomposition is shown in Figure 1.

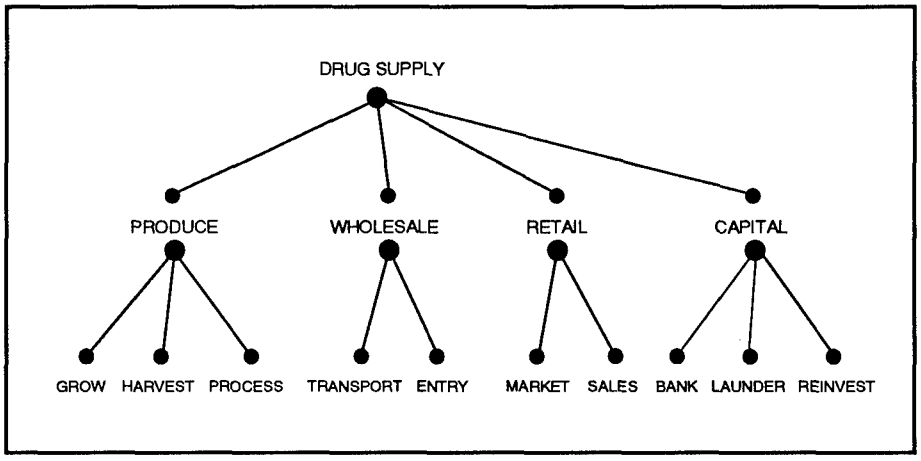

Figure 1. **Hierarchical Decomposition of Drug Supply**

For analytical accounting purposes each node was labeled to indicate its relative position and derivation within the decomposition. When numerically labeled, the decomposition took the form shown in Figure 2.

These numbers clearly are nominal. The number of factors relating to capital can be determined by counting the number of two digit labels beginning with the number four (the three factors under capital are 4.1, 4.2 and 4.3). No arithmetic can be performed with the data (labels) themselves,

Production 1			Wholesale 2		Retail 3		Capital 4		
Grow 1.1	Harvest 1.2	Process 1.3	Transport 2.1	Entry 2.2	Market 3.1	Sales 3.2	Bank 4.1	Launder 4.2	Reinvest 4.3

Figure 2. **Drug Process Accounting Scheme**

e.g. node 1.2 plus node 1.3 is meaningless, and no superiority is implied by the value of the number, e.g., node 4.1 is neither superior nor in any way more important than node 2.2. Obviously, the accounting methodology would be equally as useful if capital had been labeled as #1, wholesale as #3, production #2 and retail as #4 (with their subsets changed accordingly).

Nominal data can result from the categorization of variables. Dogs can be categorized by breed, cars by make or color, and people by religious preference or sex. If the categories are assigned numerical values, e.g., Female = 1, Male = 0 (or Female = 83, Male = 20), nominal data results. Again it does not make sense to do arithmetic with nominal data; it is meaningless to try to calculate the "average sex" from nominal data.

Nominal data, which is unique up to any one-to-one transformation, is the result of assigning labels (not necessarily numerical) to objects. An example of a one-to-one transformation, in the case of drug process accounting, is shown in Figure 3.

Production 1			Wholesale 2		Retail 3		Capital 4		
Grow 1.1	Harvest 1.2	Process 1.3	Transport 2.1	Entry 2.2	Market 3.1	Sales 3.2	Bank 4.1	Launder 4.2	Reinvest 4.3

One-To-One Transformation

Production A			Wholesale B		Retail C		Capital D		
Grow AA	Harvest AB	Process AC	Transport BA	Entry BB	Market CA	Sales CB	Bank DA	Launder DB	Reinvest DC

Figure 3. **Drug Process Accounting: One-To-One Transformation**

ORDINAL DATA AND ORDINAL SCALES

As the name implies "order" counts, and the size of the number indicates superiority and provides rank. *Webster's Dictionary* defines ordinal as "of a specified order or rank in a series" and an ordinal number as "a number designating the place (as first, second, or third) occupied by an item in a

ordered sequence." The numerical value of ordinal data indicates its relative position or standing among the data set, however, the interval between the numbers (the scale) is arbitrary, need not be consisted, and is therefore meaningless. Consequently, ordinal data cannot be combined arithmetically.

The assignment of the numerical values of 3 = superior, 2 = good, and 1 = average, creates ordinal data. It is incorrect to assume that "good," with a numerical value of two, is twice as important or valuable as "average" which has been assigned the numerical value one. The scale, a one unit interval between values, is arbitrary and could just as well have been, Superior = 648, Good = 50, and Average = 46. Because the interval is arbitrary, the values cannot be combined arithmetically. In the first case, two "Goods" (2+2) would exceed one "Superior" but in the second case two "Goods" (50+50) would remain well below one superior. The result of such arithmetic clearly is nonsensical.

Ordinal data is useful because it clearly shows relative rank among data points. An ordinal scale is invariant under monotone increasing transformations. The numerical values that represent ordinal data indicate relative superiority and rank but an ordinal scale does *not* indicate by how much one factor is preferred over another. Ordinal data *cannot* be usefully combined arithmetically.

INTERVAL DATA AND INTERVAL SCALES

Interval data is associated with a consistent and meaningful scale. In addition to indicating order and rank, one can perform addition and subtraction (but not multiplication or division) with these numbers. Interval scales have no intrinsically meaningful origin. The zero point is selected for its convenience and does not indicate the absence of the characteristic being measured. Any interval size can be used to discriminate between successive values and create the scale as long as it is used consistently.

A critical sensing element in a high performance aircraft must be connected to the instrument panel with an optical fiber cable of precisely 200 millimeters (mm) in length. The quality control engineer at the production plant measures a sample of six cables as:

200.003	200.011
199.964	200.008
200.000	199.998

By convention and to make the data easier to work with, the engineer codes the data in thousandths of a millimeter above 200. The linear transformations is

$$y = (x - 200)(1{,}000)$$

and the data set becomes

03	11
-36	08
00	-02

This set of data is interval data relative to length. The zero point does not indicate an absence of length, however, the interval is consistent and meaningful.[3] The spread between the longest and shortest price of cable (*11 -(-36) = 47 thousandths of a mm*) is preserved (*200.011 - 199.964 = .047 mm*) because addition and subtraction of interval data is permissible. Since multiplication and division are not allowed the ratio of longest to shortest is meaningless, as shown below:

$$\frac{11}{-36} = -0.3056$$

and does not equal

$$\frac{200.011}{199.964} = 1.0002$$

Another good example of interval data and interval scales are the Fahrenheit and Celsius temperature scales. The freezing point of water was assigned the value 32° Fahrenheit and 0° Celsius. Note that the zero points (0°C and 0°F) do not indicate the absence of temperature. The boiling point of water was assigned the Fahrenheit value of 212°F and the Celsius value of 100°C. The scale spacing that indicates a one degree temperature change is 1/100 for the Celsius scale and 1/180 for the Fahrenheit scale (212°F - 32°F = 180°).

Since order counts, 60°F is hotter than 15°F and because the interval between each temperature is consistent additions and subtractions are possible, e.g., 40°C + 10°C = 50°C and 160°F is 20 degrees hotter than 140°F. Because the zero point does not indicate the absence of temperature these are interval data and cannot be multiplied or divided. It is incorrect to claim that 90°F is twice as hot as 45°F. The fallacy is easily understood by considering the equivalent temperatures in both Celsius and Fahrenheit scales and comparing the two ratios.:

$$90^{\circ}F = 32.2^{\circ}C \quad \textit{and} \quad 45^{\circ}F = 7.2^{\circ}C$$

$$\frac{90^{\circ}F}{45^{\circ}F} = 2.0 \qquad \frac{32.2^{\circ}F}{7.2^{\circ}F} = 4.5$$

Are the two temperatures twice as hot, or four and one-half times as hot? To multiply and divide temperature values "absolute" scales, as discussed

2 The zero point indicates an absence of error from the specified length.

under Ratio Data and Ratio Scales, must be used.

The data in interval scales are unique up to a positive linear transformation of the form $y = a + bx$ for $b > 0$. This property of interval data allows conversion between Fahrenheit and Celsius temperatures. Adding the constant, "a", shifts all values of "x" upward or downward by the same amount, and changes the origin (zero point) of the variable "y." Multiplying by the positive constant "b" changes the size of the unit of measure. The temperature transformation is:

$$C = (F - 32)\frac{5}{9}$$

or

$$y = -\frac{160}{9} + \frac{5}{9}x$$

RATIO DATA AND RATIO SCALES

Ratio data is the most robust form of data. With ratio data size indicates absolute position and importance, the interval between values (scale) is consistent, the zero point denotes the complete absence of the characteristic being measured, and all arithmetic operations can be meaningfully performed. The critical difference between the ratio scale and interval scale is that the ratio scale has an origin that is truly a point of reference where the characteristic being measured ceases to exist.

Examples of ratio data and ratio scales abound: distance, age, money, and volume. The zero point denotes a complete absence of the characteristic in each case, larger numbers rank higher than smaller numbers and ratios are meaningful, e.g., $45,000 is truly three times larger than $15,000.

As a second example, consider temperature scales again. To avoid the limited arithmetical manipulation that can be performed with Fahrenheit and Celsius data (interval data), engineers developed an "absolute temperature scale." Unlike the temperature scales based on the freezing point of water, the derivation of the absolute temperature scale is independent of the property of any particular substance. In the absolute temperature scale, zero degrees represents the lowest attainable temperature and the absence of molecular motion. Many engineering textbooks and reference manuals clearly state that, "The absolute temperature scale should be used for all calculations" (Lindeberg, 1992). In the English System (pounds and feet) the absolute temperature scale is the Rankine scale; in the SI System[3] (kilograms and meters) the absolute temperature scale is the Kelvin Scale.

3 The SI System is an outgrowth of the General Conference of Weights and Measures, an international treaty organization that established the System International d' Unites (International System of Units) in 1960.

The data in a ratio scale is invariant under positive linear transformations of the form $y = bx$ for $b > 0$. Notice that there is no constant term which can change the location of the origin (recall *"a"* in the transformation $y = a + bx$ for interval data). In this transform the origin, where $x = 0$, will remain a zero point origin regardless of the value of *"b"*; only the slope will change.

Another attribute of a ratio scale is that equal absolute variations correspond to equal proportional variations in the data. This attribute permits the use of semi-long graphs and charts.

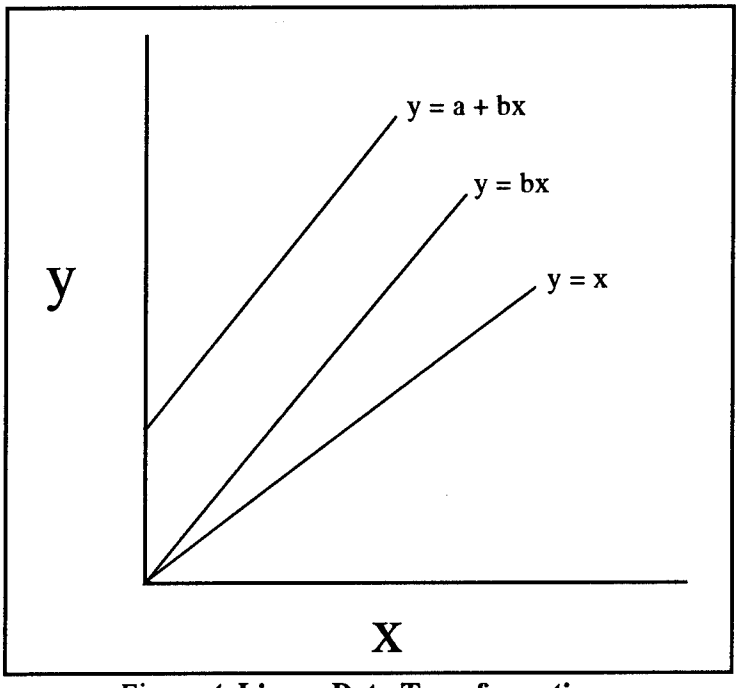

Figure 4. **Linear Data Transformations**

HOW DATA HAS BEEN MISUSED

Ship Design

A common misuse of data relates to the application of weighting factors to characteristics in an attempt to prioritize options. In the following example from a published technical paper, the subject has been changed to protect the guilty; however, all the numbers and calculations are exactly as originally published.

The objective was to select the best from among seven alternative ship designs. It was decided that the seven options (A, B, C, D, E, F, and G) should be evaluated relative to how well they responded to seventeen impor-

tant design and performance criteria. The 17 important characteristics, in no particular order, were:

Acceptability (AC) - by the market place.
Admiralty Law (AL) - total compliance or waivers required.
Environment (EN) - adverse noise, overboard discharge, etc.
Cruising (CR) - in the open ocean unconstrained.
Maneuvering (MA) - in a channel, harbor entrance, etc.
Docking (DO) - mooring and anchoring.
Ocean Navigation (ON) - without a landmass or other visual reference.
Coastal Navigation (CN) - with a landmass and other visual references.
Manning Requirement (MR) - crew size and qualification requirements.
Efficiency (EF) - fuel usage per mile.
Administration (AD) - personnel record-keeping and status monitoring.
Safety (SA) - observation, from the bridge, of unsafe conditions on deck.
Recoverability (RE) - from collision, grounding, and other accidents.
Operating Flexibility (OF) - if electrical power to bridge is loss.
Loading/Unloading (LU) - time, flexibility, and equipment availability.
Delivery Capacity (DC) - cargo capacity (weight and volume).
Design Stability (DS) - roll, pitch, and yaw.

These 17 evaluation criteria were then weighted (assigned a value indicating relative importance) with what was called a criticality factor. The most important criterion (Docking) was assigned a 1 and the least important criterion (Administration) was assigned a 17. This is clearly ordinal data from an ordinal scale, although in descending order — lower numbers indicate increased characteristic importance relative to higher numbers. It is ordinal data because it ranks the criticality factors relative to each other but reveals nothing about how much more important one characteristic is considered relative to any other. The criticality factor rated 2 is considered more important than those rated 4 and 16 but it cannot be said to be twice as important and 8 times as important respectively. The data is not interval data, e.g., the sum of the two characteristics assigned criticality factors of 2 and 3 does not equal in importance the characteristic assigned a criticality factor of 5. The criticality factors are ordinal data representing relative rank only. They cannot be meaningfully summed, multiplied, or divided.

Next, the analyst assigned the seven options a number from 1 to 7 to indicate the degree to which they possess each characteristic being used as an evaluation criteria. Again lower numbers indicate "preference," a 1 indicates the most responsiveness and a 7 the least responsiveness. See Table 1. These data again are ordinal data. They provide relative rank but the interval is arbitrary, does not indicate how much better or worse each option responds to each criticality factor, and the "zero point" (a value of 7) does not imply

an absence of response to a criticality factor.

No statistical or mathematical rule had been violated until the analyst proceeded to multiply the value of each criticality factor by the number indicating each option's responsiveness to that factor, and then summing these products for an overall evaluation of each option. The weighted summations, meant to indicate option ranking, are identified as "Totals" in Table 1 which is reproduced from the report.

CRITICALITY FACTORS			DESIGN OPTIONS						
			A	B	C	D	E	F	G
EVALUATION CHARACTERISTICS	AC	15	1	2	6	4	5	3	7
	AL	5	1	2	6	4	5	3	7
	EN	11	1	7	4	3	5	2	6
	CR	6	5	7	3	2	4	6	1
	MA	3	3	4	5	1	6	2	7
	DO	1	1	3	5	4	6	2	7
	ON	8	6	5	3	2	7	4	1
	CN	7	1	3	5	3	6	2	7
	MR	14	7	6	2	4	3	5	1
	EF	2	1	2	6	4	5	3	7
	AD	17	1	2	5	4	6	3	7
	SA	12	1	2	5	4	6	3	7
	RE	9	1	7	4	3	5	2	6
	OF	10	7	6	3	4	2	5	1
	LU	13	1	2	6	5	7	4	3
	DC	4	7	2	5	4	3	6	1
	DS	16	6	7	3	4	2	5	1
	TOTAL		471	642	658	568	727	559	651

Table 1. **Design Option Prioritization**

The report concluded that option A was the best because it had the lowest summation total; recall that the convention selected was to assign a 1 to the

most important characteristic and most responsive option while assignments of 17 and 7 indicate the least important characteristics and least responsive option respectively. The analyst also noted in the report that not only was option A preferred but that it was significantly better than the next best option (option F) because it was 88 points lower (*559 - 471 = 88*).

To determine that the analysis is flawed, one need only look at the effect of the least important evaluation criteria, Administration (AD) that was assigned a criticality factor of 17. Suppose that the apparent winning design, designated Option A, has to slight the least important criteria, Administration, in order to achieve its high ranking in most of the more important criteria. If it subsequently received the lowest ranking (7) instead of the best (1) for Administration, the swing in total points is 102 (from *17 x 1 = 17* to *17 x 7 = 119*), and Option A goes from most preferred to, at least, third place based only on a change in responsiveness to the least important factor. If Options C or G received the best rating for Administration — hypothetically relinquished by Option A — then Option A could move all the way down to fourth place.

As further demonstration of the consequences of multiplying ordinal data (treating it like ratio data, consider the following. As applied in the matrix the products are "penalty points" in that the smallest total value is the best option. The option that performed the *most important function* the worst (regardless of how badly it performs) was penalized only 7 points and is still nearly tied for first place. The option that performed the *least important function* the worst could lose everything even if it had been the best for nearly everything else, because it is penalized 119 points.

Proposal Evaluation

The following misuse of data is from a recent decision from the General Services Administration (GSA) Board of Contract Appeals, as reported in *Government Computer News* (Petrillo, 1993). In response to a procurement protest, the Board determined the Navy had made several evaluation errors. Several bidders argued that subfactor assessments should have been added to reach an overall proposal assessment; the Navy multiplied the subfactors. The Board concluded that the only reasonable approach was addition. [Was interval data treated like ratio data?]

The Board also determined that proposal evaluation errors had been made in the cost versus technical trade-off analysis. The first involved "probability analysis" where the proposal evaluators merely counted the number of tools in the offered software packages. Many of these tools had little or nothing to do with productivity and no attempt was made to determine which tools would help workers do their jobs. These productivity factors were then compared to a range of numerical weights assigned to price. This mapping of scales constituted the cost versus technical trade-off analysis. This misuse of

data types and scales contributed to the Board's decision to overturn this procurement award.

KEYS TO CORRECT ANALYSIS

Each data type and associated scale have appropriate applications. It is inefficient to always generate ratio data. If you only desire to know which option is best, not how much better than other options, subjective assessment using an ordinal scale may be all that is necessary. If each option will be evaluated by adding independent assessments of several characteristics, an interval scale can be effectively used, still assuming that only rank ordering is desired.

Depending upon the application, relaxation in the presentation of results may be appropriate and improve acceptance by avoiding valid arguments about the accuracy of subjective assessments. Assume that you have been rigorous and consistent in creating a ratio scale for the use of experts in making assessments. Several adjacently ranked options may have very small numerical separation and invite argument over their individual assessments. If the purpose of the ranking is simply to segregate the "very good," the "average," and the "poor," the results may be grouped in such a manner for presentation — even to the point of listing options alphabetically within each group — despite the fact that ratio data allows specific ranking. Remember that even the best analysis becomes impotent if not implemented or somehow utilized by the decision maker.

When querying experts to gather assessments of preferences it is critical that the responders understand the strength of the numbers they are using in their evaluations. If an expert is told to evaluate two alternatives by selecting numbers between 1 and 10, and the expert perceives that one alternative is quite a bit better than the other, values of 8 and 2 may be assigned. If, however, you intend the scale from 1 to 10 to represent ratio data, and explain that as assignment of 8 and 2 indicates that the preferred option is considered to be four times better than the alternative, the expert's assessment may change to 6 and 3 indicating that one option is really considered only twice as good as the alternative. Such a change is significant.

Words Help, but be Careful

Words can be used to convey the meaning you intend numerical values to assume, but caution is called for because individuals interpret words differently. In soliciting probability assessments, the phrases "chances are slight," "highly unlikely," and "almost no chance" have been used to suggest a probability of occurrence in the 0 percent to 15 percent range. For probabilities in the 15 percent to 45 percent range, one frequently finds descriptors such as "probably not likely," "unlikely," "improbable," and "we doubt." Attempting to verbalize a probability between 55 percent and 85 percent one

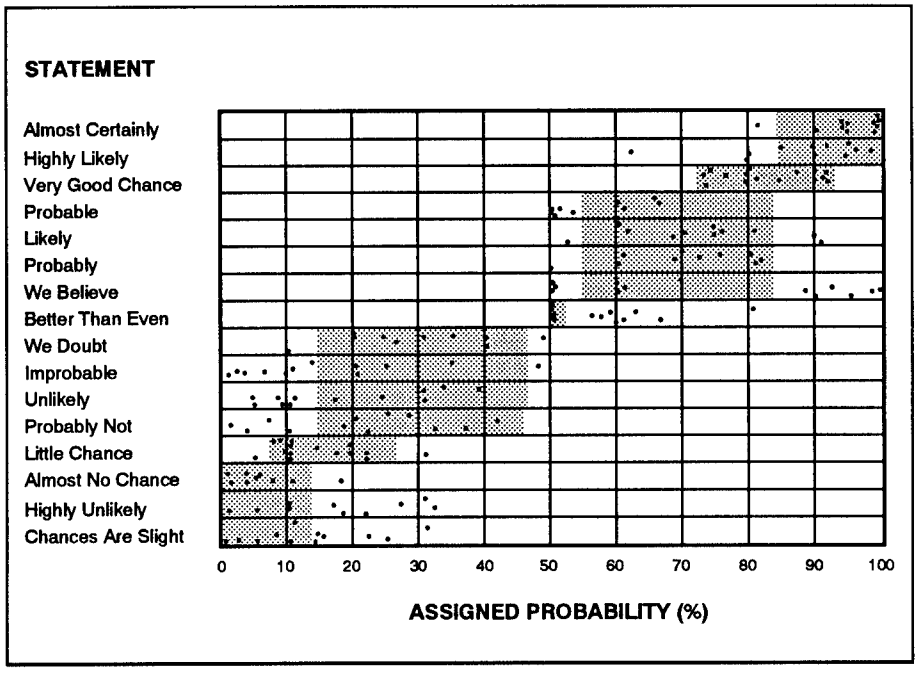

Figure 5. **Numerical Interpretation of Descriptors**

finds "we believe," "probably," "likely," and "probable." Finally, probabilities in the range of 85 to 100 percent are usually described as "highly likely," or "almost certain." When graduate students who had recently completed a course in statistics were asked to assign a probability to each of these descriptors, the results, shown in Figure 5, were not always as expected (Decision and Design, Inc., 1973).

Notice that two readers assigned probabilities as high as 30 percent to the descriptor "highly unlikely," the majority of readers interpreted "improbable" and "unlikely" as having a probability of between 0 percent and 15 percent rather than the intended 15 percent to 45 percent, and the probabilities assigned to the descriptor "we believe" ranged from just above 50 percent to over 95 percent.

The GSA Board of Contract Appeals decision discussed earlier also noted contract award discrepancies such as: "Although the solicitation described certain subfactors as being *of equal importance*, the most important of these had a maximum score more than four times greater than the least important." The Board ruled that this was too great a difference (Petrillo, 1993). Although the solicitation stated that one subfactor was "slightly more significant" than the other, the difference in weighting was 40 percent. The Board ruled that 40 percent was not "slightly more significant." The lesson to be learned is that verbal descriptors are useful, but they must be accompanied

by explicit definitions or indications of the range of values they are intended to describe.

EXPECTED UTILITIES REQUIRE INTERVAL OR RATIO DATA

The product of a probability and a utility assessment, called expected utility, is an important frequently calculated decision criteria. Probabilities are ratio data over the scale 0.0 (the certainty of non-occurrence) to 1.0 (the certainty of occurrence). The utility assessments must be unique up to a linear transformation, either interval or ratio data, otherwise erroneous interpretations can be made.

As a demonstration of the problem that can occur if an ordinal scale is used for utility assessments, consider the choice of developing one of two competing systems, A and B, that have been evaluated by engineering experts as having the following probabilities of achieving discrete levels of capability:

	Superior	Good	Poor
System A	.40	.35	.25
System B	.30	.60	.10

In assessing the utility of achieving each level of capability assume one analyst chooses an ordinal scale from 1 to 10 and lets Superior = 10, Good = 6, and Poor = 2. His calculation of the expected utility for each system is thus,

$$E(A) = (.40)10 + (.35)6 + (.25)2 = 4.0 + 2.1 + 0.5 = 6.6$$
$$E(B) = (.30)10 + (.60)6 + (.10)2 = 3.0 + 3.6 + 0.2 = 6.8.$$

He would declare that System B is preferred.

If a second analyst selected an ordinal scale from 1 to 100 and assigned Superior = 95, Good = 70, and Poor = 60, he would calculate the expected utility of each system as,

$$E(A) = (.40)95 + (.35)70 + (.25)60 = 38.0 + 24.5 + 15.0 = 77.5$$
$$E(B) = (.30)95 + (.60)70 + (.10)60 = 28.5 + 42.0 + 6.0 = 76.5,$$

and declare that System A is preferred. This preference reversal problem can be avoided by using interval or ratio scales for assessing utility when expected values will be calculated.

HIGH NUMBERS SHOULD INDICATE PREFERENCE

Sometimes it is tempting to let the numerical value one (1) represent the most preferred option with higher numbers indicating lower preference. The appeal comes from the apparent consistency of the most preferred alternative (first priority or priority one) being assigned the numerical value of one. The problem occurs in generating ratio scales where the origin indicates the absence of a characteristic or attribute. Assuming that "some large value" represents this origin, it is intuitively unappealing. The preferred convention is for higher numbers to indicate increased preference.

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PLEASE NOTE

COMING UP GOLDEN:

DEFENSE ACQUISITION BOARD REVIEW GUIDE FOR PROGRAM OFFICES

Colonel Harvey R. Greenberg, USAF
Ms. Lynn B. Palley

The purpose of this article is to document lessons learned from the Joint STARS experience, written primarily from a program office perspective, and provide suggestions for future programs facing DAB reviews. In May 1993, the Joint STARS (the Airborne Standoff Target Acquisition Recognition System used during Desert Storm) program underwent a Defense Acquisition Board (DAB) review for Low Rate Initial Production (LRIP). Originally established in the program baseline as DAB IIIA, this event was recast as the "Program Review for LRIP," since the revised DoD Instruction 5000.2 no longer provides for a DAB IIIA. However, the program review otherwise complied with almost all DAB procedures and documentation requirements.

A GOOD LANDING STARTS WITH THE APPROACH

Success — coming up golden — in the DAB process depends on "consistency, consistency, consistency!" Although each program follows its own course, DoD Instruction 5000.2 presumes that life begins with a Mission Needs Statement,

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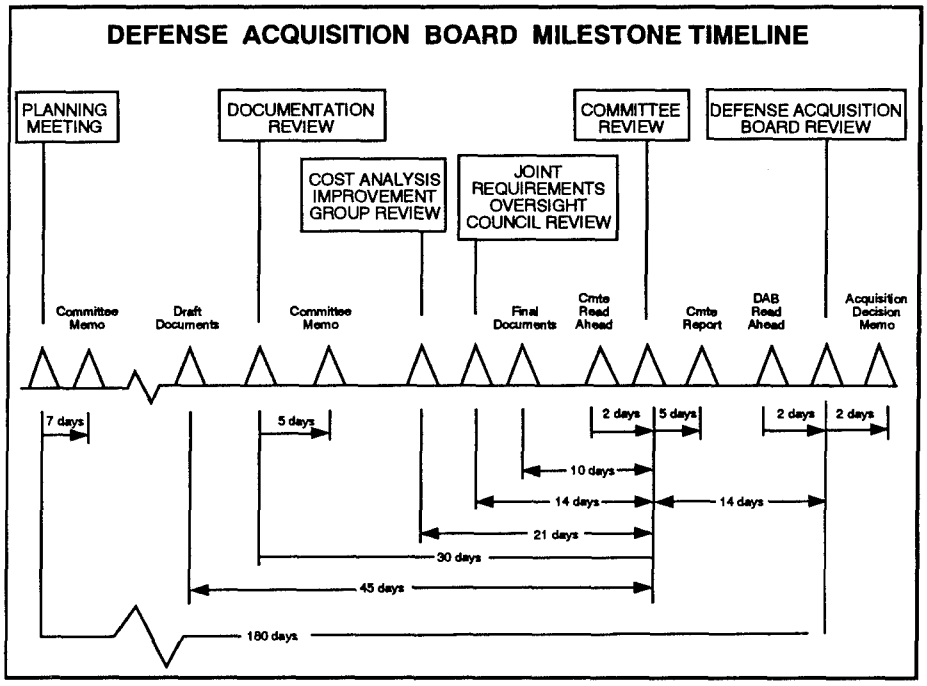

Figure 1. **From DoDI 5000.2**

from which a number of alternatives were explored, including changes in tactics, modifications to existing systems, and development of new systems such as the subject of the DAB. This model further presumes your particular system is being recommended, because a Cost and Operational Effectiveness Analysis (COEA) so indicated. In addition, it identified critical operational characteristics that flowed into the Operational Requirements Document (ORD), Acquisition Program Baseline (APB), Test and Evaluation Master Plan (TEMP), system specification, and all other aspects of your program.

While few if any programs actually evolve this way, the system will tend to force the evaluation of your program in terms of the model, and to the extent that a program conforms, the dialogue is likely to be crisper. If your program happens to resemble the model program, the risks are manageable, and the program is affordable, write it all down in the DAB documentation and you should be golden. If it differs and you have, say, two years to spruce up the foundation, the investment is well worth it.

Since the process involves both political and technical considerations, spend time before the DAB[1] to make it politically palatable. This includes strategies for cooperative development, interoperability, consideration of acquisition strate-

1 "DAB" in Pentagon jargon means both the process and the meeting (review) itself.

gies currently in vogue, and many other aspects.

PROCESS OVERVIEW

The DoDI 5000.2, Part 13, contains core guidance for DAB reviews. As shown in Figure 1, the process formally begins with a planning meeting. Subsequently, draft program documentation is prepared for review by staff of the Office of the Secretary of Defense (OSD). This commences a series of further reviews to assess documentation adequacy, some requiring OSD approval, and identify issues needing resolution.

Let me note now that a DAB *cannot* be done within the specified 180 days: (1) the time is not sufficient to prepare and coordinate the documentation; (2) the draft Cost Analysis Requirements Description (CARD) must be submitted at the planning meeting; and; (3) several processes, notably the independent cost estimate, take longer than six months.

DOCUMENTATION REQUIREMENTS OVERVIEW

Except for the CARD, required milestone documentation is listed in DoDI 5000.2, Part 11, Section C, and guidance for preparation is provided in the accompanying manual, DoD 5000.2-M. Preparation entails the concerted efforts of the program office, the using command, operational test agency, program executive officer and mission area director.[2]

The exercise is onerous, but all involved must appreciate that a favorable DAB outcome depends on affirmative OSD staff recommendations provided in the Integrated Program Assessment (IPA) (shown in Figure 2). If documentation detail is inadequate, additional actions by the program office, or delays, could ensue.

For some documents, such as the Integrated Program Summary (IPS) and TEMP, the directive clearly specifies the staffing process. For others, such as the Manpower Estimate Report (MER), unclear instructions make it sometimes difficult to determine who coordinates on the document. In effect, OSD staff have approval authority over all of documentation, and can recommend postponing the DAB or committee review.

Part 11 of DoDI 5000.2 lists documentation needed for a milestone review. Other parts proscribe life cycle documents. They include, but are not limited to:

- Systems Engineering Management Plan (SEMP)
- Computer Resources Life Cycle Management Plan (CRLCMP)

2 Under the current Air Force acquisition structure, the program office for most major programs reports to the Program Executive Officer (PEO), while the Program Element Monitor (PEM) resides in a Mission Area Directorate on the SAF/AQ staff.

- Configuration Management Plan
- Training Development Plan
- Human Systems Integration Plan (HSIP)
- Program Protection Plan (PPP)

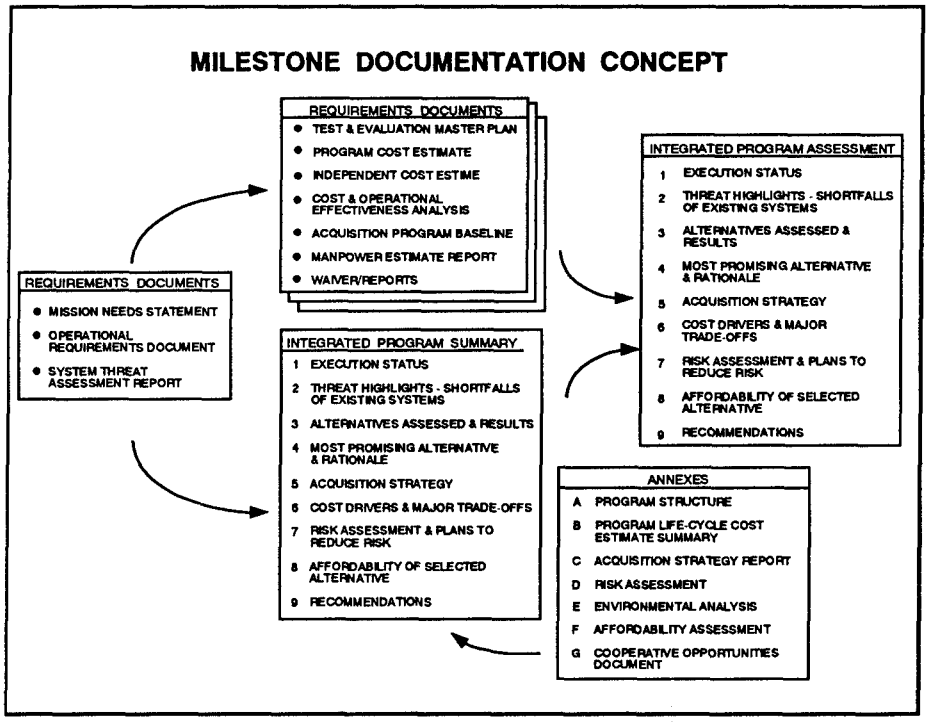

Figure 2. **From DoDI 5000.2**

Documentation requirements are agreed to at the planning meeting. In the Joint STARS DAB, OSD staffers included the Program Protection Plan and the Human Systems Integration Plan they needed for the IPA.[3] Staffers also requested a Total Quality Management Implementation Plan, unmentioned in DoD 5000.2. Though the program office should be wary about volunteering for unnecessary work by asking if a particular document is required, avoiding later surprises is important.

3 As a result of previous reviews and discussions with OSD staff, a formal Joint Requirements Oversight Council (JROC) review was not held, nor was a COEA update required.

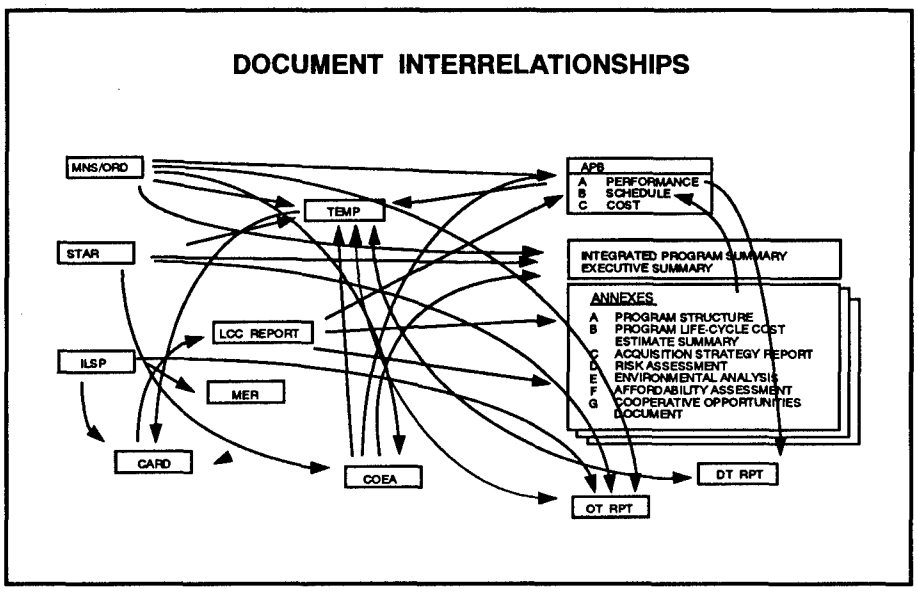

Figure 3. **Chart from DoDI 5000.2**

DOCUMENT INTERRELATIONSHIPS

Figure 3 shows major interrelationships between documents, and one could argue for several more lines. Many are direct feeds, parts of a particular document either lifted from or summarized in another, requiring consistency and accuracy. For example, the program office must summarize the life-cycle cost estimate in the IPS. Similarly, APB performance thresholds and objectives are included in the development test report as baselines against which results are reported.

OBSERVATIONS ON SPECIFIC DOCUMENTS

CARD

The CARD has the longest lead time, is required at the planning meeting in draft, and drives the independent cost estimate, which is another long lead activity. The CARD contains a system description, a Work Breakdown Structure (WBS), subsystem descriptions, software descriptions, schedules, test program descriptions (consistent with the TEMP) logistics concepts (consistent with the Integrated Logistic Support Plan (ILSP)), and many other detailed aspects of the program. While it provides the basis for a cost estimate, it does not document anything in dollars, but provides requirements which estimators price out. With its detailed technical content, it may be the most suitable document for prime contractor input.

ORD

The ORD is the cornerstone for the entire building. It provides the basis for the COEA, program content, criteria for developmental and operational testing, and other bits and pieces of program documentation. Its performance thresholds, objectives and technical parameters are included in other documents such as the APB and TEMP. Don't be surprised if cost analysts or logistics staff seek information from it.

The perfect ORD has not been written. The ORD developer is constantly told to write requirements in operational terms, yet the less specific the requirement is, the more open it is to interpretation by the tester or evasion by the developer. It must be straightforward and defendable before JROC and senior military management and staff review — particularly the operational testers — and consistent with the requirement and the COEA. And, it must be simple to allow specifics to be moved easily between documents.

The Air Force has used a "Four Star Summit" process to scrub requirements separately from a milestone review. The focus of the Summit is to ensure requirements are clear, that the system meets important requirements while not spending resources at the point of diminishing returns, and that requirements are operationally testable. It was beneficial to the Joint STARS program by focusing requirements demand and allowing consideration without the DAB process political pressures. Having agonized during the 1991 Summit, the using command in 1993 had the operational rationale for every critical requirement and could respond immediately to challenges or queries without wading through historical documentation or studies. The JROC and Army and Air Force chains of command supported the outcome, making it clear requirements would not be reopened for the DAB.

IPS

The Integrated Program Summary is the most important DAB document, cross-referencing much documentation, and touching on virtually every program aspect. The IPS is the document an OSD staffer will turn to first in writing the Integrated Program Assessment. The program office should spend time with the guidance in DoD 5000.2 and use a successful example before starting work.

The heart of Annex A, the Program Structure, is a master schedule, which should also support the APB. The guidance for Annex A seems to suggest it consists of one chart, but as staff elements engage it, it may grow. Annex B, the Program Life-Cycle Cost Estimate Summary, should be drawn from the stand-alone cost documentation submitted to the CAIG, as specified by DoD 5000.2-M. You should have a understanding with OSD on definitions of cost elements, fiscal years to be shown, base years, and other aspects of the annex, which may change at the last minute as a result of Service or OSD Cost Analysis Improvement Group (CAIG) reviews.

Annex C, the Acquisition Strategy Report (ASR), requires a substantial

INTEGRATED PROGRAM SUMMARY

FOR

(PROGRAM TITLE)

1. **Decision Requested** .....
.....

2. **Program Description** .....
.....
.....
.....

Acquisition Category____ **Program Element** _____ **Project Number**___

PREPARED BY

Program Executive Officer or Designated Component Official: **Program Manager:**

_____ **Date** ____ _____ **Date** _____

CONCURRENCE

User's Representative:

_____ **Code** _____ **Date** _____

APPROVAL

_____ **Code** _____ **Date** _____
(DoD Component Acquisition Executive)

Figure 4. **IPS Cover Sheet Format**

amount of data, including broad acquisition strategy, Federal Acquisition Regulations (FAR) clauses and logistics support plans. Though interaction with OSD staff will vary depending on the reviewer, the Joint STARS lesson learned is: Follow the guidance *exactly*, and be prepared to provide additional information. Policy is evolving, and there are differing views between OSD and the services on who determines and approves the acquisition strategy, vis-à-vis the Acquisition Plan that the Service Acquisition Executive (SAE) approves.[4] Getting to the DAB on time suggests flexibility here and a team effort between the program manager, Procurement Contracting Officer (PCO) and OSD reviewer.

4 Change 1 to DoDI 5000.2 specifies ASR approval is now required prior to release of the request for procurement (RFP).

Annex D, the Risk Assessment, is another up-front-and-early document. It will probably be widely circulated on the OSD staff, including the CAIG for consideration in the cost estimate, and it may generate questions and plant visits. Annex E, Environmental, is somewhat general, and environmental concerns vary with current events. Get your program office or product center focal point together with the appropriate OSD staffer early, and stay tuned for new legislation and regulations. If your budget does not show compliance with a new law, it is not OSD's problem!

Though DoD 5000.2-M guidance on the Affordability Annex seems to require charts showing your program in relation to broad aggregates, expect direction by OSD staff on what comparisons to make. The OSD analyst will likely be more interested in a mission area rather than Service topline. As the program office does not generally have access to mission area data, you will need headquarters help, as did Joint STARS. Revising the annex took place at the eleventh hour, and in retrospect soliciting guidance earlier in the process would have been worthwhile.

Annex G, the Cooperative Opportunities Document, is a challenge because of the political nature of international events and the number of players. For Joint STARS, no one would offer guidance on how to write it, but there was no shortage of criticism when the document was submitted.

APB

The APB is the only one of the Service-prepared documents the Under Secretary of Defense (Acquisition & Technology) (USD(A&T)) signs. It consists of three sections — performance, schedule, and cost — and is prepared using OSD software that controls formats and the change process. Since it is virtually the only document that survives the DAB, the OSD staff will review it with a fine toothed comb.

Check the guidance to ensure the minimum milestone set is covered, but also research the definitions. Joint STARS revised its APB to include "Required Assets Available" and provided what seemed to be an appropriate date. However, the program office's interpretation did not conform to Air Force policy and OSD analysts picked up on it when the milestones appeared out of sequence. So, keep your definitions simple, and ensure milestones are consistent with all schedule information. Section C, cost, will likely be a last-minute update due to the CAIG process. A talking paper explaining the proposed APB will help considerably.[5]

TEMP

The TEMP requires the cooperation and coordination of the program office,

5 When the APB is updated between milestones, it must be accompanied by a Baseline Change Request memo. For a milestone review, it is just another DAB document.

user, test activities and Services. Joint STARS showed that meeting OSD expectations is difficult, and that DoDI 5000.2 requirements amass detailed annexes. Even with strong leadership and discipline, the TEMP may delay the DAB.

Joint STARS began revising the draft TEMP before the DAB clock started, but after a year the document was getting dated. The draft elicited extensive comments from OSD staff reviewers, including some offices normally not expected to see the document. Though an acceptable TEMP was submitted in time for the DAB, it required an OSD meeting, an interagency tiger team and lots of follow-up to get the signatures. Lessons learned were:

- Assemble an interagency team *empowered to make decisions for their organization.* You do not have the time to incorporate action officers' input only to find that their managements have different views.

- Document the process in writing. Task people, get their input and prepare signed meeting minutes. Respond to each point.

- Keep the program director and Program Executive Officer (PEO) informed. You are more likely to need general officer help on the TEMP than any other document.

DT Report

The DoDI 5000.2 contains no guidance on this report, except to say that it reports the results of DT. Joint STARS prepared such a report a year before the DAB for authorization of Advance Procurement and had developed a good working relationship with the OSD(T&E) staff. The program office and OSD maintained an open line of communications.

MER

The MER presents some unique challenges. Its preparation is a using command responsibility requiring support from the program office and every affected command.[6] All players and independent cost teams need to incorporate data from the MER into the Operations and Support (O&S) estimates. Spend some time defining ownership and the chain of command. Though Joint STARS avoided show stoppers, a kickoff meeting with the sponsor and manpower shop followed by a tasker might have made the process smoother.

6 This could include users in several different theaters, any depot which performs item management or provides government furnished equipment (GFE), Air Training Command, and other organizations.

OPERATIONAL TEST REPORT OR ASSESSMENT

Although the operational test agency reports through a different chain of command, the program office has a direct stake in the report's content and timeliness. Even with the arms-length relationship, open communications and cooperation are essential, and the program office should be able to comment on the draft before it goes to the Pentagon. Though views may differ, the program office can help eliminate any errors.

MANAGING THE DOCUMENTATION PROCESS

Except for the formal DAB-minus-180 day planning meeting, documentation preparation will consume the process until the drafts are submitted 45 days before the DAB. Preparing documentation is worse than merely time consuming; it is also tedious. If all drafts are submitted on time and satisfy OSD, chances are the DAB will occur as scheduled or close to it. Otherwise, it will be delayed.

Each document must have one person (editor) responsible. Each must be broken down into components so that each author understands what and when to feed to the editor. All documents must march to the same schedule.

Aside from scheduling, the major issues in document preparation are content and consistency. While DoD 5000I.2 provides very specific guidance for some documents, guidance for others may be general or nonexistent.

In providing a foundation for the document, you should :

- Acquire all of the regulatory references, and examples from other programs that have recently gone through the process.

- Develop a vision or outline, and provide it to the team members. As a document editor, you are likely to find yourself working with specialists who, while well versed in their technical disciplines, do not understand the DAB process, the purpose of the document, or the target audience.

- Realize quality counts. Several Joint STARS documents were accepted with no change between draft and final submission, and workload for the "final" copies was limited to changing the cover and reproducing the body.

- Consider establishing a management information system strategy, but make sure it does not develop into a choke point.

- Contact an OSD reviewer for guidance and perform "expectations management."

Though informal contacts can help the process, they must be controlled through a program office clearinghouse that understands who is talking to whom and ensures only reasonable commitments are made. Closing the loop with the

PROGRAM OFFICE/SERVICE DOCUMENTATION SUMMARY			
Document	**Who Prepares**	**Guidance**	**Who Signs or Approves**
Mission Needs Statement (MNS)	User	DoD 5000..2-M	Joint Requirements Oversight Council (JROC)
Operational Requirements Document (ORD)	User	DoD 5000.2-M	Service Chief of Designated Representative
Integrated Program Summary (IPS)	Program Office	DoD 5000.2-M	PD, PEO, User, SAE
System Threat Assessment Report (STAR)	Component Intelligence Command	DoD 5000.2-M	DIA
Manpower Estimate Report (MER)	User	DoD 5000.2-M & Supplemental Guidance from OSD(FM&P)	USD(A)
Test & Evaluation Master Plan (TEMP)	Program Office	DoD 5000.2-M	PD, PEO,OTA, User, SAE, DOT&E, DDR&E(TE)
Cost & Operational Effectiveness Analysis (COEA)	User	DoD 5000.2-M	
Acquisition Program Baseline (APB)	Program Office	DoD 5000.2-M	PD, PEO, SAE, USD(A&T)
Cost Analysis Requirements Document (CARD)	Program Office	DoDI 5000.4 & Supplemental Guidance from OSD CAIG	
Program Office Life-Cycle Cost Estimates	Program Office	DoD 5000.2-M	SAE
Development Test Report	Program Office	No Format Specified	Director, Test Activity
Operational Test Report	OTA	No Format Specified	Commander, OTA

Table 1. **Program Office/Service Documentation Summary**

Service staff, especially the PEO action officer and program element monitor, is important so all are saying the same thing. For the IPS, Joint STARS used briefing charts for the initial outline and established positions on sensitive issues, helping senior management assign appropriate resources to the IPS writing team.

Joint STARS attempted several times to estabish a formal review process, but this added no value, perhaps because an implied certification created anxiety and reviewers were reluctant to sign. Staff summary packages were not used at all, since they habitually take too long and result in excessive editing. In the end, Joint STARS relied heavily on the program office DAB coordinator and PEO

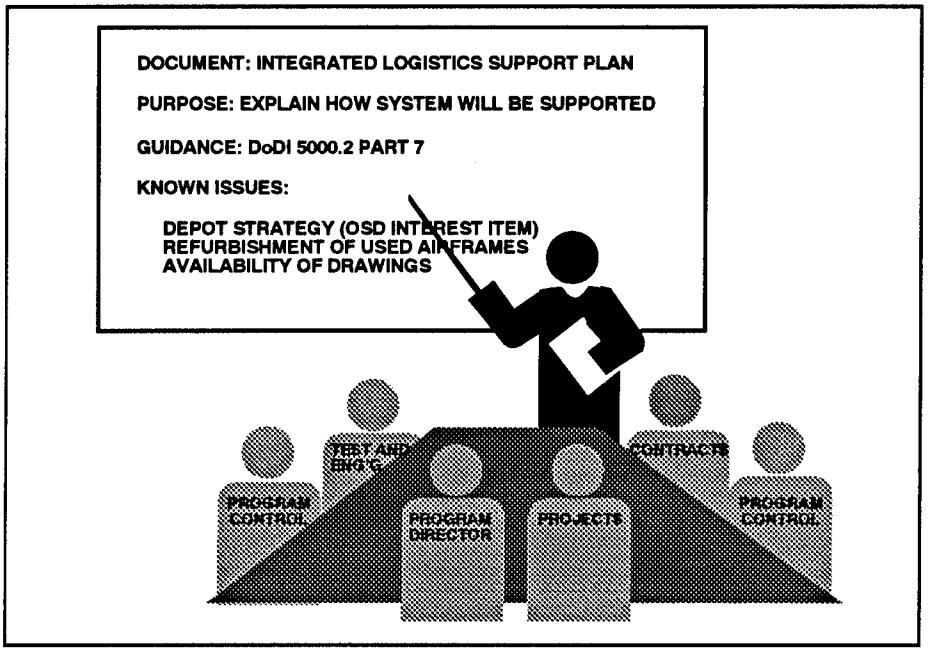

Figure 5. **Judicious use of briefings for complex or high risk documents can help secure guidance and resources before writing begins and also expedite final review.**

action officer for final review and consistency check, and this informal arrangement worked satisfactorily.

The documentation schedule must include a window for early OSD review. This lesson was relearned the hard way in the case of the Acquisition Strategy Report. Through an intense effort by the program office and PEO, including a two day turnaround on questions and a Pentagon meeting, a potential delay was avoided. The mechanics of sharing draft documentation must be worked through the Service headquarters, as some documents will have a Service stakeholder while others will not.

As the deadline for documentation approaches, the Service team needs to manage last minute activities carefull. Just understand who is doing what, so that the day after the deadline, if some documents are missing, at least someone knows where they are!

Managing the Schedule

Managing your program in the DAB process is an enormous effort. Because of the number of events and organizations involved, strict schedule discipline is mandatory. Using a schedule (PERT and/or GANTT) detailing DAB activities can provide management assistance. Activities identified would include required documentation, briefings, reviews, tests, and any other others which must

be completed prior to the DAB. Each activity should be further broken into a series of subtasks and measurable events. An OPR for each should be designated and held accountable.

Working with external organizations is particularly critical, since they have other priorities and might not be stakeholders in your DAB review. Make sure they buy in to your schedule. If a DAB-critical milestone is in jeopardy, the external organization's chain of command may be able to make a difference, but only if used in time.

The schedule requires daily review to identify which OPRs need to be contacted to discuss progress and problems being encountered, matters crucial to understanding where the program stands towards achieving its scheduled DAB Review. Keeping up with the schedule is a full time job. Finding the best person to do it is the most important assignment a program manager facing a DAB can make.[7]

ORCHESTRATING DAB EVENTS

Preplanning Meeting

Perhaps the most critical event is the one not shown on the official DAB schedule: an informal preplanning meeting which allows the OSD and Service teams to develop preliminary documentation. Four months from the planning meeting through draft document submission is generally not enough time to prepare a document. This meeting encourages team building, and the Service team begins the process of "expectations management" through a heads-up on required documentation.[8]

Planning Meeting

As specified in DoDI 5000.2, the planning meeting assesses readiness for the DAB and plans for documentation. The program manager should attend, for not doing so places the program in peril. The program office DAB coordinator can brief the program overview (including why the program is ready for a review) and recommendations for what documentation should be required and the review schedule. (These should have been negotiated earlier with OSD.)

The planning meeting output will be a memo from the DAB committee chair to the DAB Secretary and the Service Acquisition Executive (SAE) recommending the program go forward, establishing the required documentation, identifying major issues, and providing specific guidance. For example, in Joint STARS program concurrency was raised as one of several issues, and the Air Force was

7 This individual was a support contractor. Other program officies tend to appoint someone at the Major or GS-13 level.

8 The Joint STARS preplanning meeting was held five months before the formal planning meeting.

requested to address its need and risks. The planning meeting does not schedule the DAB, but it does indicate that a DAB may be forthcoming. The OSD's official posture is to await submission of *suitable* draft documentation and then update the DAB calendar after the documentation review.

The 4-1/2 half months between the planning meeting and documentation review provide an opportunity to work issues and possibly arrange for staff visits to the program office, contractor, or both. As a minimum, you can count on visits by the independent cost team(s).

Documentation Review

Upon submission of draft documentation, OSD will schedule a documentation review. The program manager will brief to the outline specified in DoDI 5000.2. Joint STARS followed the outline exactly. Draft documentation submission kicks off an intense activity period for the program and OSD. If staffers see a substantial amount for the first time, or if it does not comply with the guidance memorandum, you risk a delay.

The documentation review outcome will be a memo, and you can expect a number of action items and off-line activities. Though the documentation will prompt many comments and questions, you should work with the OSD staff to distinguish between these and specific changes that need to be made to the document in order to make the final submission acceptable. Regardless of which category the comment falls in, respond specifically and document the answer.

CAIG Review

The CAIG review will culminate months of activities by independent cost teams. Because of congressional criticism regarding the "independence" of the independent cost estimate (ICE), policy and procedures are changing in this area. Salient events in the Joint STARS ICE exercise included:

- Preparation of a draft CARD and submission at the formal planning meeting,
- Visits by the Air Force ICE team from the Air Force Cost Analysis Agency to the program office and the contractor,
- Visits by the OSD CAIG staff to the program office and the contractor,
- Visits by both agencies to the proposed depot, as well as to an AWACS operational unit for analogies,
- Voluminous amounts of paper flowing between the program office, contractor, and ICE teams supplementing the CARD,

- Submission of initial cost estimates and documentation by program office and Air Force ICE team by the financial management staff in the Office of the Air Force Secretary for review,
- A week-long reconciliation meeting between the program office and Air Force ICE team,[9]
- Revised estimates and cost documentation by both parties as indicated during reconciliation discussions,
- Two formal Air Force CAIG reviews, with an additional meeting after the first CAIG session failed to resolve differences in the time allowed,
- Adoption of a Service cost position by the Air Force CAIG,
- A major program restructure to reduce the disconnects to a level which the Air Force could commit to fund,
- Submission of program office estimate, Air Force ICE, and service cost position to the OSD CAIG,
- OSD CAIG review,
- A two week delay to the CSC review to allow the OSD CAIG to review the cost documentation on the restructured program, and
- Follow-up meetings after the OSD CAIG review, the Committee review, and the DAB to establish the USD(A) position.

The fundamental process issues from the Joint STARS DAB were the relationship between the OSD ICE and the Air Force ICE, and the Service/OSD reconciliation process. On the former, the issue revolved around whether the OSD team actually did an ICE, vice using the Air Force ICE team as an extension of themselves. On the latter, the process simply does not provide for a Service/OSD reconciliation, nor is it clear who would arbitrate.

While policy makers will no doubt refine the process in the next few years, the program office must treat development of its cost estimate and support to the ICE as a live-or-die exercise. Some lessons learned or relearned were:

9 Reconciliation ensures both teams costed the same program and allocated costs to the same accounts. It is not arbitration.

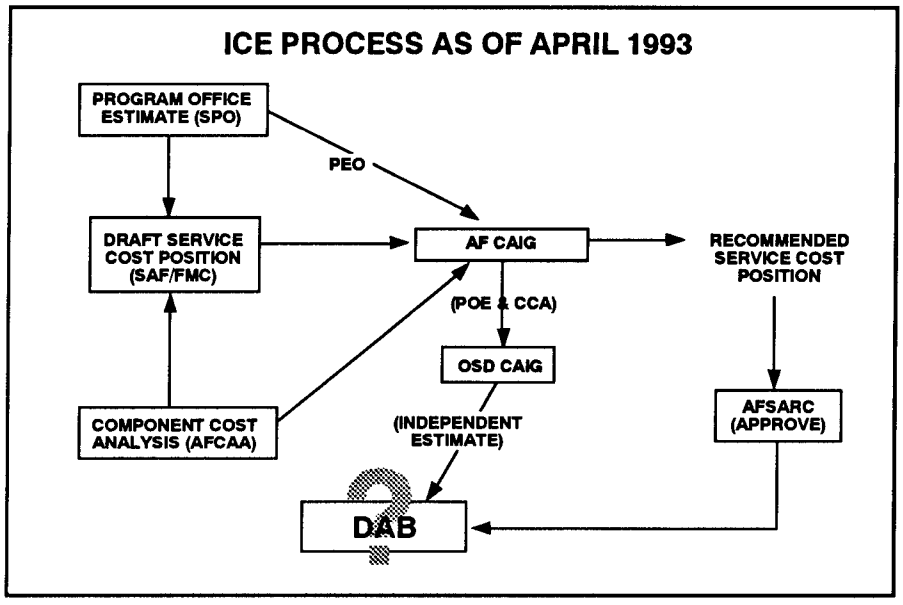

Figure 6. **ICE Process as of April 1993**

- You cannot underestimate the resources required to support all the cost estimate activities. Augmentees from the product center's "home office" can make a significant contribution.

- Teamwork between OSD, the Service ICE team, the Headquarters staff, the program office, and the contractor are essential.

- Though the CARD will never be sufficient to perform an estimate, it is both necessary and useful.

- Strict baseline discipline is crucial, especially when the program is evolving. You can't recover in time if teams diverge too far on what is being costed.

- Your cost documentation must be of quality to allow another team to reproduce your estimate.

- Since the ICE will without fail increase your required line, you must be prepared to adjust available funding and content at the 11th hour and support your new program estimate. However, be aware programs can be killed due to cost growth which is really unnecessary risk dollars.

- Know the strengths of your methodologies and stay consistent with the storyline, establishing program office credibility up front.

- Be prepared for in-depth reviews, to negotiate, and to take action items - recheck your facts off line rather than spontaneously giving an incorrect reply.

- Where you cannot agree, at least agree on how to characterize the differences.

- Use a quick turnaround, flexible automated costing model to prepare the estimate, funding profiles and documentation; and

- Take advantage of this process to gain insight into the weaker, less defined areas of the program office estimate by comparing your information to the independent estimates.

JROC Review
Since there were no issues requiring resolution, a JROC review did not take place. For those programs undergoing a JROC, the format for the review is canned, and you and the using command should obtain a current template from the JROC Secretariat.

Air Force Systems Acquisition Review Council (AFSARC) Review
The Air Force meeting equivalent to a DAB occured the week before final documentation was due. It approves the program that will go forward to OSD. Since the program was already providing ACAT I documentation, the AFSARC imposed no additional unique requirements. However, following the program office/Air Force CAIG reconciliation the program had a $900M disconnect. The program office had worked out a rephasing with the concurrence of Air Combat Command, and it was the rephased program (with roughly a $300M disconnect) which the AFSARC approved and promised to funD,[10] and the Program Office Position and Service Cost Position cost position thus became the same.

Final Document Submission and Committee Review
While draft documentation is defined as documentation over the PEO's signature, final documentation for the IPS, APB, and TEMP must have an SAE

10 Strictly speaking, policy requires the program to be funded. An IOU was accepted because the ongoing "Bottom Up Review" made it impossible for the Air Force to offer offsets.

signature.[11] The OSD staff emphasized the need to submit change-bar versions from the drafts for some of the major documents, and complying with this request was worth some midnight oil. Accordingly, the program office provided change-bar versions and a talking paper summarizing the changes.

Like the documentation review, DoDI 5000.2 also specifies the format of the briefing to the committee. Several days before the review the PEO and committee chair decided the briefing should focus on issues, and some of the required topics were not presented. This phase of the review process is where teamwork between OSD, the Air Staff, and program office really pays off. Though OSD and the Air Force disagreed on a number of issues, the program director knew what they were, and all Air Force attendees were prebriefed on the background and Air Force position. The cooperation between the PEO and Mission Area Director and their respective staffs was outstanding. Everyone involved had only one agenda: a successful DAB. During this period, staffs also began work on finalizing the APB, exit criteria for the next phase, and the wording of the Acquisition Decision Memorandum (ADM).

DAB Review

Though DoDI 5000.2 suggests a briefing outline along the lines of the IPS executive summary, the Joint STARS DAB briefing was issue oriented. The program needs a "yes," and unresolved issues risk either a "no" or a non-decision.

Joint STARS had an unresolved issue of program cost. Since this was the first DAB for the newly appointed USD(A&T), the OSD staff had no feel for expectations or even who was invited. Because of differences in cost estimates, the decision was delayed, but a compromise was reached a few days after the review and a timely ADM was received. Completed staff work also allowed the USD(A&T) to approve exit criteria and the APB in the ADM, vice assigning action items which would have needlessly extended the process another few months.

SUMMARY

Upon assuming command of the Joint STARS program, with only five months to go before the DAB, the new program manager called everyone into the auditorium and, dressed in BDUs and helmet, declared war on the DAB. In fact, prosecuting a DAB is probably as close to war as acquisition people can expect to get. Like war, there is only one objective and the stakes are high.

In the case of the Joint STARS program, a contract for advance procurement (long lead) had been let 13 months ago, betting that the DAB would not only

11 Only certain documents require signature pages. For others, signature can mean forwarded with a cover memo.

approve production, but approve it in time to avoid a work stoppage and possibly loss of funds as the fiscal year end approached.

Like war, everyone — program office, contractor, headquarters, and elsewhere — needs to execute the same battle plan. If your program is sound, if leadership supports you, if you stay focused, and if you keep sprinting until the finish line, everything will work out. You may even wind up with a better program. Good luck!

READERS SPEAK

Article May Discourage New PMs

Your new quarterly reached me in Australia where I am spending a year helping the Australian DoD with C/SCSC implementation. Keeping up with developments in the U.S. DoD from such a far off location is not easy. So, your quarterly is like a candle. I found Walter LaBerge's item especially interesting. However, Major Christensen's paper worries me.

Let me say first that I have complete confidence in the data that Christensen analyzed and in the statistical techniques that he used in his analysis. I know that defense contracts overrun more often than they underrun. It is the conclusion that program managers have habitually understated their estimates at completion that I think is dangerous and likely to lead to even greater overruns.

Christensen borrows a point that some in OSD have been making for years based on their DAES data base, the source of his information. Their statistics show that once a contract develops a serious cumulative cost variance it is very unlikely to recover. They don't say that contracts never recover, as can be seen in Christensen's Table 1, but they make the point that it is rare enough that when a program manager forecasts recovery the forecast should be viewed with great skepticism. Christensen goes on to prove that, on average, past program managers have underestimated the final overrun on their programs throughout the life of the contract. This is attributed to the PMs' advocacy, over optimism, and unwillingness to face reality, rather than the PM's attempts to control the final cost.

What message does that bring to the tender ears of a prospective PM attending the Defense Acquisition University? Obviously, recovery is impossible and your bosses won't believe you if you predict it. Therefore, to attempt recovery is futile; to forecast it may be career damaging! Giving that message will have the opposite result from what is intended. Christensen and others seek "realism" in PM estimates at completion. But an EAC that assumes recovery will not happen becomes a self fulfilling prophecy. The goal should be to have the PMs predict what they hope to achieve through their corrective actions, as well as what the outcome is likely to be if they don't succeed. The DAES now

requires both pieces of information. It remains to be seen if PMs get away with telling OSD what will happen if they don't succeed, without having somebody in the Pentagon take away all of their funding.

It has been said that those who ignore the lessons of history are doomed to repeat them. But concentrating on our preponderance of programs that overran can lead to the conclusion that repeating history is almost unavoidable. That's not what we want defense managers to believe. There are programs that have not overrun, and others that have worked their way out of serious cost and schedule difficulties. Perhaps your *ARQ* might better focus on them.

JAN C. PETERSON
Director of Program Evaluation
Strategic System Program Office
U.S. Navy

Compliments and Suggestions

I was very pleased with the quality of the first issue. The *ARQ* is an important and valuable forum for the discussion and development of acquisition policy. As an active participant in preparing a Navy ACAT-IV program for Milestone IIA and III Acquisition Review Board decisions, I found a real gap between DoD policy guidance at the 5000 level and implementation by program offices. Assets such as *ARQ* may help add value to what are now pro forma exercises.

Please consider some suggestions for future issues.

Comparative acquisition. The GAO and others have published interesting reports on acquisition approaches taken by other nations such as France and its professional acquisition corps. Israel and the United Kingdom should provide some innovative ideas on meeting requirements within budget constraints. It would be interesting to see what ex-Soviet design bureaus, such as MiG, are doing now. I think this area has potential for a regular feature or a series of articles.

Case studies. I believe the case study approach to management pioneering by the Harvard Business School can be a springboard for discussion as well as an illustration of how to implement and apply policy. I would think that some recent system acquisitions would be interesting and useful. Successful and troubled acquisitions can both provide useful lessons learned. The V-22 Osprey and the SEAWOLF programs would seem to be rich sources of material.

Fiftieth anniversary of DoD. The National Security Act of 1948 established the Department of Defense and gave the Secretary of Defense responsibility for acquisition policy for all services. A year long series starting in 1997 and culminating with the fiftieth anniversary could examine the evolution, success-

es, and failures of DoD acquisition policy. The history of OSD is an interesting one. This series could tie in the observance of DoD's founding, if one is planned.

Sincerely yours,

DONALD A. PETKUS
ILS Manager
Mass Memory Storage Device
Naval Surface Warfare Center
Crane, IN

I just finished reading Vol. 1, No. 1 of *ARQ*. It is an outstanding contribution to the field of defense systems acquisition. If I had reservations about *ARQ* as a nascent publication, it was how it would complement Program Manager (which, needless to say, I also think is an outstanding publication). That reservation was clearly settled in the first issue.

The *ARQ* is strategic in nature and is a forum for fresh new ideas. Furthermore, it included a good cross section of issues that must be mastered by defense managers to provide and adequate defense during a time of budget scarcity.

I look forward to future issues and stand ready to provide any assistance you may require.

Best regards,

MICHAEL N. BELTRAMO
President
Beltramo & Associates
Los Angeles, CA

Calculation Error

I've just finished browsing through your inaugural issue of the *ARQ*. Although I'm grateful such a publication exists, I do feel compelled to point out errors.

The article which sparked my interest was "Variance Analysis with C/SCSC" by Mr. George J. Chambers. I certainly do not consider myself an expert in this field, but do feel I know enough to highlight an egregious error on his part, your editorial boards's part, and/or both. The table on p. 74 is presented as the capstone of his article; the summarization of what C/SCSC is about. There's just

one thing... it's wrong! Mr. Chamber's calculation of cost variance (CV) is not what he (and others) define it to be on p. 73: CV = BCWP - ACWP. Although his comments on each case are consistent with what the CV should have been, something got lost inn the translation. I'm sure you can understand how extremely confusing this could be, and probably was, to many of your readers.

Please accept my observations as they are intended, constructive and with the hope the ARQ can become the "premier acquisition publication."

JEFFREY K. YOUNG
Aeronautical Systems Center
Wright-Patterson AFB, OH

Thank you for your fine journal. I found the articles to be interesting informative, and timely. I hope you will continue to find quality articles to publish in this new undertaking.

You may wish to include in your next number some corrections regarding the last article on variance analysis. The formulas and tables shown under the heading "ANALYSIS CASES" are in serious error, and are inconsistent with the formulas for schedule and cost variance given on page 71, and with the discussion of the cases that follows. The discussion appears to have followed the correct values of SV and CV rather than the incorrect ones printed. On page 74, the values is the table in the SV column should not have "X" as part of the result. Also the values in the CV column are all incorrect, except for the first zero, and should not have "X" as part of the result. Apparently the incorrect formula CV = (ACWP - BCWS)/BCWS was used to compute the numbers in this column.

KEN ROGERS
NCCOSC
San Diego, CA

Mr. Chambers Responds

Mr. Chambers responded, "I have reviewed the comments and find them justified. Corrections are attached. My intent was not to include any absolute dollar values as this would have led to a lengthy discussion about where the values come from, which was not germane to this article." Mr. Chambers corrected table appears on page 184.

EDITOR

Corrections to:
"Variance Analysis Within C/SCSC Programs"

George J. Chambers

The table on page 74 of Vol. 1, No. 1, has several data errors in the SV and CV columns. A corrected Table is submitted. The author wishes to thank the reviewers for their comments and regrets these errors and apologizes for any confusion that they may have caused.

CASE	BCWS[a]	BCWP[b]	ACWP[c]	SV[d]	CV[e]
1	$X	$X	$X	0	0
2	$X	0.50X	0.75X	-0.50X	-0.25X
3	$X	0.75X	0.50X	-0.25X	+0.25X
4	$X	0.75X	0.75X	-0.25X	-0.0X
5	$X	0.75X	X	-0.25X	-0.25X
6	$X	1.25X	X	+0.25X	+0.25X
7	$X	1.25X	1.25X	+0.25X	+0.0X
8	$X	X	.75X	0	+0.25X
9	$X	X	1.25X	0	-0.25X
10	$X	0.75X	1.25X	-0.25X	-0.50X
11	$X	1.25X	.75X	+0.25X	0.50X
12	$X	1.25X	1.50X	+0.25X	-0.25X
13	$X	1.50X	1.25X	+0.50X	+0.25X

a: Budgeted Cost of Work Scheduled (Planned Work)
b: Budgeted Cost of Work Performed (Actual Earned Value)
c: Actual Cost of Work Performed
d: Schedule Variance (BCWS)
e: Cost Variance (BCWP - ACWP)

In the cases illustrated in the table, Schedule Variances (SV) and Cost Variances (CV) are described as a percentage of BCWP as listed in the second column (or "X," rather than absolute dollar values) using the definitions on page 73. They are not Schedule Variance Percent (SVP) or Cost Variance Percent (CVP), which would be obtained by applying the formula on page 71.

The definitions used for SV and CV in this example have been added to the subscripts. Also, the definition of the column superscripts is incorrect: "e" should be "d" and "f" should be "e." These are corrected in the above table.

GUIDELINES FOR AUTHORS

The Acquisition Review Quarterly (ARQ) is interested in manuscripts representing scholarly examination, disciplined research and supported empirical experience in the fields of defense systems management and acquisition management. Defense acquisition is the pirmary focus, but papers covering other fields of management will be considered. Manuscripts supporting the Defense Acquisition University (DAU) commitment to improve the acquisition process and the professionalism of the acquisition workforce are particularly welcome.

STYLE GUIDELINES

Manuscripts must be clear, concise and interesting with a well-organized development of ideas. The Publication Manual of the American Psychological Association, Third Edition, should be followed for reference style and general guidelines. Copies of the manual may be ordered for $19.95, plus handling of $3.50, from APA, 750 First Street, N.E., Washington, D.C. 20002. Orders charged to VISA or Mastercard are accepted by calling (202) 336-5500. Sexist language must be avoided.

When preparing a manuscript for publication, the author(s) must follow these instructions:

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- Lengthy quotations (300-500 cumulative words from one source) require written permission from the copyright holder for reproduction. Adaption of tables and figures also require such approval. It is the author's responsibility to secure such permission, and a copy of the publisher's written permission must be provided the ARQ editor immediately upon acceptance of the article for publication in the ARQ.

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- Full-length articles generally should not exceed 4,000 words (approximately 15 pages of double-spaced, typewritten copy including references, tables, and figures).

- Short articles of 600 to 1500 words that describe new practices, programs, and techniques will be considered for each issue. Authors should have additional background or supplemental information for interested readers. Articles of similar length that describe a research or analytical approach that may enhance understanding of the acquisition profession will also receive strong consideration.

- Send the material in Word Perfect 5.1 on a 3 1/2" or 5 1/4" diskette and

two hard copies. If Word Perfect 5.1 is unavailable, send in ASCII format for conversion. Identify software program and operating system.

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